

# **Evaluating policy impacts of minimum energy performance standards (MEPS) on Nigeria's Nationally Determined Contribution (NDC) to the Paris Agreement**

A thesis approved by the Faculty of Environment and Natural Sciences  
at the Brandenburg University of Technology Cottbus–Senftenberg  
in partial fulfilment of the requirement for the award of the academic degree  
of Doctor of Philosophy (Ph.D.) in Environmental Sciences

by

Master of Science, Environmental and Resource Management

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Day of the oral examination: 17 December 2020



## DECLARATION

I hereby declare that this thesis has not been previously published or written by another person; neither has it been submitted nor accepted for any other academic award. It is the result of my original work carried out at Brandenburg University of Technology (BTU) Cottbus – Senftenberg, Germany, within the framework of the Ph.D. Programme “Environmental and source Management”. All materials from other sources have been duly and adequately acknowledged.

Anayo Azubuike Ezeamama

Original signature

Cottbus, August 2019.

## **DEDICATION**

I dedicate this work to my children, Chukwuebuka, Munachimso, and Chimbusomma. I love you all so dearly. And in loving memory of my late father, Nze Paulinus Ezeugo Ezeamama.

## ACKNOWLEDGEMENT

My special appreciation and utmost gratitude go to Prof. Dr. iur. Eike Albrecht, Head of the Department of Public Law with focus on Environmental and Planning Law, at the Brandenburg University of Technology (BTU), Cottbus-Senftenberg, Germany for granting me the opportunity to carry out this research under his expert supervision which facilitated in many ways the accomplishment of this dissertation. My sincere appreciation is extended to the Graduate Research School (GRS) at BTU for the studentship awarded to me for the completion of this research. I also thank the GRS for providing other related funding and short fellowships (conference travel grants, funding for a research stay, research assistant positions) awarded to me during the course of this research. I gratefully acknowledge all the support I received from colleagues and supervisors at the Copenhagen Centre on Energy Efficiency (C2E2) during my visiting scholar program under the United Nations (UN) Environment – Danish Technical University Partnership (UDP). I also wish to express my deep appreciation to the European Union (EU) ERASMUS+ Program for providing financial assistance for my visiting scholar program. I am grateful to the International Energy Agency (IEA) in Paris for accepting me in the training program on “Energy Efficiency in appliances and equipment” which provided relevant background knowledge for my thesis. I also wish to express my profound gratitude to the German Academic Exchange Service “Deutscher Akademischer Austauschdienst” (DAAD) for awarding me the 2015 “DAAD Prize for outstanding achievement by a foreign student at a German University”. The award was a pronounced recognition and served as a great motivation to put in more effort towards my academic pursuit.

I would like to appreciate Prof. Dr. agr. Bachar Ibrahim for his insightful suggestions that contributed to the progress of this research. I also would like to appreciate the assistance of Dr. Michael McNeil for his guidance, through numerous telephone discussions, on the application of the modeling tool adopted in this study. Also, I wish to thank Dr. Patrick Blake for his assistance in gaining access to some important data and for providing clarifications whenever it is needed. I extend my sincere gratitude to the American Council for an Energy-Efficient Economy (ACEEE) for awarding me the prestigious “Linda-Latham Scholarship” that enabled my participation in the 2016 summer school program on “Energy Efficiency in Buildings” in Pacific Grove,

California. Participation in the summer school program also provided significant contacts that facilitated access to important data relevant for my research.

I remain grateful to colleagues at the department (notably, Ms. Madlen Muschka, Mr. Dirk Marx) for their encouragement and support. I also thank Dr. Lutz Phillip for reviewing the German abstract of this dissertation.

My sincere gratitude is extended to all key informants at government ministries, departments and agencies (MDAs), NGOs, Enugu Electricity Distribution Company (EEDC) in Nigeria who granted my interview requests and follow-up telephone discussions and e-mail correspondences. Your insightful assistance and expertise information is well appreciated. I will not forget to appreciate all respondents from the case study area for their participation in my survey.

I owe my deepest gratitude to my mother, Mrs. Margaret Ezeamama, and my sisters, Dr. Lady Chy Emele and Ms. Loretta Ezeamama for their continued support and encouragement. Special thanks also go to my friends and well-wishers for their constant support during this research.

## ABSTRACT

The Nigerian government has set ambitious national energy and emissions savings target in the Nigeria's Nationally Determined Contribution (NDC) to the Paris Agreement. Improvement in economy-wide energy efficiency is part of the measures stipulated in the NDC to achieve this established national energy and emissions savings goals. As a result, Nigeria has developed policy measures (such as minimum energy performance standards – MEPS) which is aimed at reducing the energy consumption of appliances and contribute to mitigating CO<sub>2</sub> emissions from the electricity sector. It is expected that the implementation of MEPS will also help to address the challenges of unreliability of electricity supply and facilitate the desired energy-efficient appliance market transformation. The MEPS currently covers the three most energy consuming electrical products in households (lighting, refrigerators and air conditioners) as identified in the metering study of the Energy Commission of Nigeria. Based on data collected from a household survey and relevant government institutions, this research assessed the environmental performance and energy savings impacts of the current MEPS in households to understand the contribution of the current MEPS to national energy and emissions savings goals and to identify the potential for improvements of the current MEPS. The research also investigated the role of institutions and the existing policy framework in advancing energy efficiency and transforming the appliance energy efficiency market in Nigeria. The author conducted a survey of 384 households in the case study area of Enugu and six key government institutions that are directly involved in advancing end-use energy efficiency. Data on current appliance ownership trend and saturation rates, usage patterns, appliance age distribution, number of appliances and their power ratings, appliance per unit energy consumption were gathered both from the survey and from secondary sources. These data are needed to establish baseline energy consumption against which to measure the potential policy impacts of MEPS. Data retrieved from relevant government agencies comprise of technical details of current standards, information on the current status of appliance energy efficiency policies, planned and ongoing policy delivery mechanisms and the responsible institutions. Three different policy scenarios were conceptualized to model the policy impacts of current MEPS: a scenario assuming no MEPS or a business-as-usual (BAU) scenario, a policy scenario (PS) that takes the current Nigerian MEPS into con-

sideration and an aggressive policy scenario (APS) that assumes the scaling up of the current MEPS to more stringent levels (guided by best commercially available technologies in selected literature). Unit energy consumption (UEC) for the covered products were defined for each of the policy scenarios. The policy analysis modeling system (PAMS) was adopted to study energy and emissions savings potential from the institutionalized MEPS. It is assumed that policies are introduced in 2019 and forecasts were projected through 2030. The integrated policy framework was also adopted as evaluation criteria to identify policy gaps in the existing end-use energy efficiency policy measures and the identification of possible policy overlaps was conducted using content analysis. Based on the results, the replacement of existing stock of the reviewed appliances in the surveyed households with products that meet current MEPS would reduce annual residential electricity demand by 37 %. Leapfrogging to a more stringent standard for the modeled products would result in a 67 % reduction in household electricity consumption compared to BAU. To put the results into context, savings estimates were evaluated based on the capacity to mitigate the existing electricity supply-demand gap in the case study area. As a result, taking into the cognizance the estimated average annual electricity consumption of 3330 kWh per household in Enugu (ECN, 2013a, p. 133), the total energy savings from the assessed products can provide electricity for 42.4 and 73 households in the policy and aggressive policy scenarios respectively. 39 % of annual CO<sub>2</sub> emissions from the surveyed households can be avoided through the implementation of the current standard. Scaling up current standards to more stringent levels would reduce annual CO<sub>2</sub> emissions from the assessed households by approximately 67 %. National level policy impacts show that the implementation of the current MEPS would contribute about 8.5 % of the national target of achieving 179 MtCO<sub>2</sub> greenhouse gas (GHG) emissions reduction as established in the Nigeria's NDC while leapfrogging to a more aggressive MEPS level would cover about 11.3 % of the national emission reductions targets by 2030. Even though end-use energy efficiency policy framework as detailed in the national energy efficiency action plan (NEEAP) is based on the integrated policy approach, key implementation strategies/instruments for components of the integrated policy (such as financial incentives and environmentally sound management (EnSM) systems) are either lacking or still in their planning stages. Furthermore, the result from the content analysis reveals that institutional roles for the advancement of end-use energy efficiency as detailed in the action plan, are in



some cases, not assigned based on the statutory mandates of the respective institutions. This creates room for possible overlaps in the discharge of duties of the relevant government agencies. To achieve a successful energy-efficient appliance market transformation and to realize the estimated savings as derived in this study, the research recommends the following actions: conduct large-scale baseline energy efficiency market survey to provide a detailed picture of current baseline efficiency levels which will ensure that MEPS are set at levels higher than current market baseline; adopt and implement policy instruments (especially incentive measures and EnSM) to improve the attractiveness of energy-efficient products and reduce the potential environmental impacts from the use and disposal of products, review the roles of relevant government agencies in advancing appliance energy efficiency to ensure that roles are assigned in line with the statutory mandates of institutions.

**Keywords:** Energy efficiency policy, Minimum Energy Performance Standards (MEPS), Nationally Determined Contribution (NDC), Paris Agreement, Ministries, Departments and Agencies (MDAs), Households, Appliances, Energy and Emissions.

## ZUSAMMENFASSUNG

Die nigerianische Regierung hat sich ein ambitioniertes, nationales Energie- und Emissionseinsparungsziel hinsichtlich Nigerias national festgesetztem Beitrag (NDC) zum Pariser Abkommen gesetzt. Die Verbesserung der gesamtwirtschaftlichen Energieeffizienz ist Teil der Maßnahmen innerhalb des NDC, um das festgesetzte nationale Energie- und Emissionseinsparungsziel zu erreichen. Das hatte zum Ergebnis, dass Nigeria Politikmaßnahmen (wie Standards für minimale Energienutzung – MEPS) entwickelt hat, die darauf abzielen, den Energiekonsum von Haushaltsgeräten zu reduzieren und zur CO<sub>2</sub>-Emissionsreduktion im Stromsektor beizutragen. Darüber hinaus geht man davon aus, dass die MEPS-Umsetzung dazu beiträgt, die Herausforderungen der unzuverlässigen Energieversorgung zu adressieren und die gewünschte Transformation zu energieeffizienten Haushaltsgeräten zu ermöglichen. Laut einer Messstudie der Nigerianischen Energiekommission deckt MEPS aktuell drei der am meisten Energie konsumierenden Elektrogeräte in Haushalten ab (Beleuchtung, Kühlschränke und Klimaanlage). Auf der Grundlage von Daten, die von Haushalten und relevanten Regierungsbehörden erhoben wurden, bewertet diese Forschungsstudie die Umweltperformance und die Auswirkungen von Energieeinsparung der aktuellen MEPS in Haushalten, um den Beitrag der aktuellen MEPS an den nationalen Energie- und Emissionseinsparungen zu verstehen und Verbesserungspotentiale der aktuellen MEPS zu identifizieren. Die Forschungsstudie untersucht auch die Rolle von Institutionen und der aktuellen politischen Rahmenbedingungen bei Energieeffizienzverbesserungen und der Transformation von Märkten für energieeffiziente Haushaltsgeräte in Nigeria. Der Autor hat eine Befragung von 384 Haushalten im Fallstudiengebiet Enugu und in sechs Schlüsselregierungsbehörden, die direkt in die Verbesserung der Energieeffizienz von Endgebrauchsgeräten involviert sind, durchgeführt. Es wurden Daten gesammelt sowohl durch Befragung als auch aus sekundären Quellen zu aktuellen Trends bei dem Besitz von Geräten und Zufriedenheitsraten, Gebrauchsmustern, Gerätealterverteilung, Geräteanzahl und deren Energieverbrauchsbewertung, Geräte pro Energieverbrauchseinheit. Die Daten werden benötigt, um eine Baseline für den Energieverbrauch zu ermitteln, gegen welche die Verbesserungspotentiale der MEPS-Politikwirkungen gemessen werden können. Daten, die von

relevanten Regierungsbehörden erhoben wurden, beinhalten technische Details aktueller Standards, Informationen zum aktuellen Stand bei Politikmaßnahmen zur Haushaltsgeräteenergieeffizienz und bei geplanten oder in Umsetzung befindlichen Politikmaßnahmen und Anlieferungsmechanismen und diesbezüglich verantwortlicher Institutionen. Drei unterschiedliche Politikscenarien wurden konzeptualisiert, um die Auswirkungen der aktuellen MEPS-Politikmaßnahmen zu modellieren: ein Szenario nimmt keine MEPS oder das Business-as-usual (BAU) Szenario an, ein Politikscenario (PS) berücksichtigt die aktuellen MEPS in Nigeria und ein aggressives Politikscenario (APS), das die Verstärkung der aktuellen MEPS und stringenterer Niveaus (geleitet von den besten, kommerziell verfügbaren und aus der Literatur ausgewählten Technologie) vorsieht. Der Energieverbrauch pro Einheit (UEC) wurde für die untersuchten Produkte für jedes Politikscenario definiert. Das Politikanalysemodellsystem (PAMS) wurde an den Untersuchungsrahmen angepasst, um das Energie- und Emissionseinsparungspotential des institutionalisierten MEPS zu untersuchen. Es wurde angenommen, dass 2019 Politikmaßnahmen eingeführt wurden, auf deren Basis die Entwicklung bis 2030 prognostiziert wurde. Der integrierte Politikansatz wurde auch als Vergleichsmaßstab angewendet, um Unzulänglichkeiten in den existierenden Politikmaßnahmen für Energieeffizienz von Endgebrauchsgeräten zu identifizieren. Zudem wurde die Content Analyse angewendet, um mögliche Politiküberlagerungen zu identifizieren. Laut den Ergebnissen der Studie würde die Ersetzung der untersuchten aktuellen Haushaltsgeräte in den befragten Haushalten mit Produkten, die die aktuellen MEPS einhalten, die Stromnachfrage von Haushalten um 37% reduzieren. Der Wechsel zu stringenteren Standards für die modellierten Produkte würde in eine 67% Reduktion der Stromnachfrage im Vergleich zum Status quo (BAU) resultieren. Um die Ergebnisse in einen Bezug zu setzen, wurden die Energieeinsparungsschätzungen basierend auf der Kapazität bewertet, existierende Stromangebots- und Nachfragerücken im Fallstudiengebiet zu reduzieren. Das hat zum Ergebnis, dass die Energieeinsparungen von den untersuchten Produkten 42,4 zusätzliche Haushalte unter dem PS-Szenario und 73 zusätzliche Haushalte unter dem aggressiven Politikscenario versorgen können, wenn man den jährlichen Durchschnittsenergieverbrauch von 3330 kWh pro Haushalt in Enugu (ECN, 2013a, S. 133) zugrunde legt. 39% der jährlichen CO<sub>2</sub>-Emissionen der befragten Haushalte kann vermieden werden, wenn die aktuell geltenden

Standards eingehalten werden. Der Wechsel zu stringenteren Standards würde die jährlichen CO<sub>2</sub>-Emissionen um 67% reduzieren. Die Auswirkungen auf nationaler Ebene zeigen, dass die Umsetzung der aktuellen MEPS dazu führen würde, dass 8,5% des nationalen Ziels bei den 179 MtCO<sub>2</sub>-Treibhausgasemissionsreduzierungen (GHG), wie sie in Nigerias NDC aufgeführt werden, erreicht würden. Der Wechsel zu aggressiveren MEPS-Niveaus würde 11,3% der nationalen Emissionsreduktionsziele bis 2030 abdecken. Auch wenn der Politikrahmen für die Endgebrauchsenergieeffizienz, wie im nationalen Energieeffizienzaktionsplan (NEEAP) festgehalten, auf dem integrierten Politikansatz basiert, fehlen Schlüsselumsetzungsstrategien und –instrumente bzw. befinden diese sich lediglich in der Planungsphase für die einzelnen Komponenten des integrierten Politikansatzes (wie etwa finanzielle Anreiz- und umweltfreundliche Managementsysteme (EnSM)). Des Weiteren enthüllen die Ergebnisse der Content Analyse, dass institutionelle Verantwortlichkeiten für die Verbesserung der Energieeffizienz von Endgebrauchsgeräten, wie im Aktionsplan ausgeführt, in einigen Fällen nicht gemäß den gesetzlichen Vorgaben der Institutionen zugeteilt sind. Das schafft Raum für mögliche Überlagerungen bei der Zuteilung von Verantwortlichkeiten der relevanten Regierungsbehörden. Um eine erfolgreiche Transformation des Marktes für energieeffiziente Haushaltsgeräte zu schaffen und die geschätzten Energieeinsparungspotentiale zu realisieren, die in dieser Studie abgeleitet wurden, empfiehlt diese Forschungsarbeit die folgenden Aktionen: Ausführung einer großflächigen Baseline-Marktbefragung zur Energieeffizienz, um ein detailliertes Bild des aktuellen Status Quos des Effizienzsniveaus herzuleiten, das gewährleistet, dass die MEPS auf Niveaus angesetzt werden, die höher sind als die aktuellen Marktniveaus; Anpassung und Umsetzung von Politikinstrumenten (besonders Anreizmaßnahmen und EnSM), um die Attraktivität energieeffizienter Produkte zu verbessern und das Potential von Umweltauswirkungen der Nutzung und Entsorgung von Produkten zu reduzieren; Überprüfung der Rollen von Regierungsbehörden, die für die Verbesserung der Energieeffizienz von Haushaltsgeräten relevant sind, um sicherzustellen, dass Verantwortlichkeiten im Einklang mit den gesetzlichen Vorgaben dieser Institutionen verteilt sind.

# TABLE OF CONTENTS

DECLARATION.....	III
DEDICATION .....	IV
ACKNOWLEDGEMENT .....	V
ABSTRACT.....	VII
ZUSAMMENFASSUNG .....	X
TABLE OF CONTENTS .....	XIII
LIST OF FIGURES .....	XVII
LIST OF TABLES .....	XVIII
LIST OF ABBREVIATIONS.....	XIX
1. INTRODUCTION.....	1
1.1 GENERAL STATEMENT.....	1
1.1.1 NIGERIA ELECTRICITY SECTOR DEVELOPMENT, CURRENT STATUS AND CHALLENGES .....	4
1.1.2. EVOLUTION OF ENERGY EFFICIENCY POLICIES IN NIGERIA .....	6
1.2 PROBLEM FORMULATION .....	8
1.2.1. ENERGY-RELATED CHALLENGES .....	8
1.2.2 BASELINE DATA.....	11
1.2.3 ENERGY SECTOR AND CLIMATE CHANGE .....	12
1.3 A CASE FOR ENERGY EFFICIENCY STANDARDS .....	13
1.3.1 ENERGY EFFICIENCY FOR GREENHOUSE GAS MITIGATION.....	13
1.3.2 ENERGY EFFICIENCY FOR GREENHOUSE GAS MITIGATION – NATIONAL CONTEXT.....	15
1.4 AIM AND OBJECTIVES OF THE STUDY .....	17
1.5 RESEARCH QUESTIONS. ....	18
1.6 RESEARCH HYPOTHESES. ....	18
1.7 SIGNIFICANCE OF THE RESEARCH.....	19
1.7.1 SIGNIFICANCE OF THE CHOICE OF ENUGU .....	21
1.7.2 TARGET AUDIENCE .....	22
1.8 SCOPE AND LIMITATIONS.....	23
1.9 MOTIVATION .....	25
1.10 DEFINITION OF TERMS .....	27
1.11 THESIS OUTLINE .....	29
2. LITERATURE REVIEW .....	31
2.1 INTRODUCTION TO CHAPTER TWO.....	31
2.2 GENERAL LITERATURE REVIEW.....	31
2.2.1 ENERGY EFFICIENCY POTENTIAL .....	32
2.2.2 ENERGY EFFICIENCY GAPS AND BARRIERS .....	33
2.2.3 METHODOLOGY FOR ENERGY EFFICIENCY POLICY IMPACT ASSESSMENT .....	34
2.3 TYPES OF ENERGY EFFICIENCY POTENTIAL .....	35

2.4 POLICY DESIGN – THE CHOICE OF INSTRUMENTS TO CLOSE ENERGY EFFICIENCY GAPS .....	37
2.4.1 THE INTEGRATED POLICY APPROACH.....	41
2.4.2 POLICY ASSESSMENT CRITERIA – A CONCEPTUAL CONSIDERATION.....	47
2.5 THEORETICAL FRAMEWORK .....	48
2.5.1. PATH DEPENDENCE THEORY .....	49
3. METHODOLOGY .....	51
3.1 INTRODUCTION TO CHAPTER THREE.....	51
3.2 SCIENTIFIC RESEARCH POSITIONING .....	51
3.2.1 EMPIRICAL RESEARCH APPROACH.....	53
3.3 METHODS OF DATA COLLECTION .....	57
3.3.1 PRIMARY DATA.....	57
3.3.2 SECONDARY DATA.....	62
3.4 DATA ANALYSIS .....	63
3.4.1 QUALITATIVE APPROACH.....	63
3.4.2 QUANTITATIVE APPROACH.....	64
4. OVERVIEW OF NIGERIA AND STUDY AREA.....	75
4.1 INTRODUCTION TO CHAPTER FOUR .....	75
4.2 LOCATION AND GEOGRAPHY .....	75
4.3 CLIMATE.....	77
4.4 DEMOGRAPHY.....	78
4.5 POLITICAL SITUATION.....	80
4.6 ECONOMY .....	81
4.7 ENERGY AND ENVIRONMENTAL PROBLEMS.....	81
5. RESIDENTIAL SURVEY – DATA ANALYSIS.....	83
5.1 INTRODUCTION TO CHAPTER FIVE.....	83
5.2 DESCRIPTIVE STATISTICAL ANALYSIS .....	83
5.3 CALCULATION OF POTENTIAL POLICY IMPACTS.....	89
5.3.1 LIGHTING.....	89
5.3.2 REFRIGERATORS.....	93
5.3.3 ROOM AIR CONDITIONERS .....	100
5.4 RESULTS AND DISCUSSION .....	104
5.4.1 REFRIGERATOR.....	104
5.4.2 ROOM AIR CONDITIONERS .....	108
5.4.3 LIGHTING.....	112
5.5 CHAPTER CONCLUSION .....	115
5.5.1 DISCUSSION OF UNCERTAINTIES.....	119
6. REVIEW OF THE INSTITUTIONAL MANDATES AND GOVERNANCE OF KEY MDAs IN THE APPLIANCE ENERGY EFFICIENCY SUB-SECTOR.....	120
6.1 INTRODUCTION TO CHAPTER SIX .....	120
6.2 BACKGROUND.....	121

6.2.1 FEDERAL MINISTRY OF POWER.....	122
6.2.2 FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY .....	124
6.2.3 ENERGY COMMISSION OF NIGERIA .....	124
6.2.4 FEDERAL MINISTRY OF ENVIRONMENT.....	126
6.2.5 STANDARDS ORGANISATION OF NIGERIA .....	128
6.3 ANALYSIS OF INTERVIEW AND QUESTIONNAIRE DATA.....	131
6.4 RESULTS AND DISCUSSION .....	132
6.5 CHAPTER CONCLUSION .....	135
7. REVIEW OF RELEVANT INTERNATIONAL ENVIRONMENTAL CONVENTIONS AND PROTOCOLS. .	135
7.1 INTRODUCTION TO CHAPTER SEVEN.....	135
7.2 BACKGROUND.....	135
7.3 REVIEW OF INTERNATIONAL ENVIRONMENTAL REGIMES NIGERIA IS A SIGNATORY .....	137
7.3.1 THE PARIS CLIMATE AGREEMENT .....	137
7.3.2 THE MONTREAL PROTOCOL .....	138
7.3.3 THE KIGALI AMENDMENT TO THE MONTREAL PROTOCOL .....	140
7.3.4 THE MINAMATA CONVENTION ON MERCURY .....	140
7.4 CHAPTER DISCUSSION.....	141
7.4.1 IMPROVING ENERGY EFFICIENCY OF REFRIGERATOR AND AIR CONDITIONER IN THE CONTEXT OF THE MONTREAL PROTOCOL AND PARIS CLIMATE AGREEMENT .....	142
7.4.2 IMPROVING LIGHTING EFFICIENCY IN NIGERIA IN THE CONTEXT OF THE PARIS CLIMATE AGREEMENT AND THE MINAMATA CONVENTION ON MERCURY .....	145
8. ENERGY EFFICIENCY POLICY ASSESSMENT – THE NIGERIA NATIONAL ENERGY EFFICIENCY ACTION PLAN (NEEAP).....	146
8.1 INTRODUCTION TO CHAPTER EIGHT.....	146
8.2 BACKGROUND.....	147
8.3 EVOLUTION OF ENERGY EFFICIENCY POLICIES IN A REGIONAL CONTEXT .....	148
8.3.1 ARTICLE 43 OF THE ECOWAS ENERGY PROTOCOL .....	149
8.3.2 ECOWAS ENERGY EFFICIENCY POLICY .....	151
8.4 ECOWAS INTEGRATED POLICY FRAMEWORK.....	151
8.5 ASSESSMENT OF THE NEEAP.....	154
8.5.1 MINIMUM ENERGY PERFORMANCE STANDARD.....	154
8.5.2 NEEAP – SUPPORTING POLICY MEASURES .....	157
8.5.3 NEEAP – MONITORING, VERIFICATION AND ENFORCEMENT .....	159
8.5.4 NEEAP – ENVIRONMENTALLY SOUND MANAGEMENT .....	161
8.6 CHAPTER DISCUSSION.....	162
8.6.1 ANALYSIS OF THE MEPS AND SUPPORTING POLICIES .....	162
8.6.2 ANALYSIS OF MONITORING, VERIFICATION AND ENFORCEMENT .....	164
8.6.3 ANALYSIS OF ENVIRONMENTALLY SOUND MANAGEMENT .....	165
8.7 CHAPTER CONCLUSION .....	166
9. HOUSEHOLD LEVEL BARRIERS AND POLICY SOLUTIONS.....	167
9.1 INTRODUCTION TO CHAPTER NINE.....	167

9.2 RELIABILITY-FOCUSED BEST PRACTICE ENERGY EFFICIENCY PROGRAMS .....	173
10. CONCLUSION AND RECOMMENDATIONS.....	178
10.1 INTRODUCTION TO CHAPTER TEN.....	178
10.1.1 CONTRIBUTIONS OF THE DISSERTATION.....	178
10.2 MAIN CONCLUSIONS CONCERNING THE RESEARCH QUESTIONS .....	179
10.3 RECOMMENDATIONS.....	183
10.4 FURTHER RESEARCH .....	186
REFERENCES.....	187
APPENDIX.....	205
I. QUESTIONNAIRE (HOUSEHOLD SURVEY).....	205
II. QUESTIONNAIRE (INSTITUTIONAL MANDATES AND ROLES OF KEY MDAs).....	212
III. QUESTIONNAIRE (ENUGU ELECTRICITY DISTRIBUTION COMPANY - EEDC) .....	215
IV. LIST OF RELEVANT NATIONAL ACTS AND LAWS.....	216
V. RELEVANT INTERNATIONAL CONVENTIONS NIGERIA IS A SIGNATORY .....	216



## LIST OF FIGURES

Figure 1.1 Electric power consumption (kWh per capita) .....	4
Figure 1.2 Distribution of power access and power outage per studied zone. ....	22
Figure 2.1 fundamental aspects of the MVE process .....	45
Figure 2.2 Institutional transformation of appliance market through the integrated policy approach.....	46
Figure 3.1: Top-down and Bottom-up method .....	54
Figure 3.2 Top-down approach.....	64
Figure 3.3 Bottom-up approach.....	67
Figure 3.4 Overall research framework .....	74
Figure 4.1 Map of Enugu state highlighting case study areas .....	77
Figure 5.1 Age distribution of respondents .....	84
Figure 5.2 Education level of respondents .....	84
Figure 5.3 Occupation distribution of studied area.....	85
Figure 5.4 Household decisions on electricity consumption.....	85
Figure 5.5 Average duration of electricity availability in surveyed households.....	86
Figure 5.6 Factors that influence consumers' choice of appliance .....	87
Figure 5.7 Information sources that may influence consumers' purchase decision .....	88
Figure 5.8 Electricity billing methods.....	89
Figure 5.9 Types of refrigerator and freezer units in the surveyed households .....	94
Figure 5.10 Refrigerator-freezer size distribution .....	94
Figure 5.11 Age distribution of refrigerator-freezers.....	95
Figure 5.12 Breakdown of the purchase status of refrigerators.....	96
Figure 5.13 Types of air conditioners in visited households .....	101
Figure 5.14 Age distribution of room air conditioners .....	102
Figure 5.15 Energy consumption (kWh) for different scenarios – refrigerator .....	106
Figure 5.16 Energy consumption (kWh) for different scenarios – room air conditioners .....	110
Figure 5.17 Energy consumption (kWh) for different scenarios – lighting .....	114
Figure 5.18 End use comparison of projection scenarios for the covered products.....	118
Figure 6.1 Questionnaire data analysis process.....	132
Figure 8.1 Comparison of labelling information .....	163

## LIST OF TABLES

Table 1. 1 Key GHG mitigation strategies.....	17
Table 3. 1 Forecast parameters.....	71
Table 3. 2 Life time assumed for covered products.....	72
Table 4. 1 Poverty ranking of Enugu State .....	79
Table 4. 2 Physical and socio-economic characteristics of Nigeria .....	80
Table 5. 1 Distribution of incandescent light bulbs by power ratings .....	90
Table 5. 2 Refrigerator parameters .....	99
Table 5. 3 Comparison of MEPS levels in different economies for a 280 L fridge-freezer.....	100
Table 5. 4 Room air conditioner parameters .....	103
Table 5. 5 Refrigerator household level policy impacts .....	104
Table 5. 6 Refrigerator national policy impacts.....	108
Table 5. 7 Room air conditioner household level policy impacts .....	109
Table 5. 8 Air conditioner national policy impacts .....	111
Table 5. 9 Comparison of MEPS levels in different economies for 3.5 kW cooling capacity room air conditioners. ....	112
Table 5. 10 definition of UEC for lighting and corresponding CO <sub>2</sub> emissions. ....	112
Table 5. 11 Lighting household level policy impacts.....	113
Table 5. 12 Lighting national policy impacts.....	114
Table 6. 1 Overview of institutional roles and mandates .....	130
Table 6. 2 Indicative roles played by key institutions in championing end-use energy efficiency .....	134
Table 8. 1 ECOWAS mandatory specifications for CFL lamp efficacy .....	152
Table 8. 2 comparison of lamp efficacy with regional standards.....	155
Table 8. 3 MEPS for AC in Nigeria categorized based on EER for each energy class and star rating .....	156
Table 8. 4MEPS for refrigerators in Nigeria categorized based on EEL for each energy class and star rating .....	157
Table 8. 5 Wattage and price range of incandescent and CFL bulbs in the case study.....	164

## LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
ACEEE	American Council for an Energy-Efficient Economy
ADB	Asian Development Bank
APS	Aggressive Policy Scenario
AU	African Union
AV	Adjusted volume
BAT	Best Available Technology
BAU	Business-as-usual
CES	Carbon dioxide emissions savings
CFC	Chlorofluorocarbon
CFLs	Compact Fluorescent lamps
CH <sub>4</sub>	Methane
CLASP	Collaboration Labelling and Appliance Standards Programme
CO <sub>2</sub>	Carbon dioxide
COP	Conference of the Parties
CREDC	Community Research and Development Centre
DisCos	Electricity Distribution Companies
EC	European Commission
ECN	Energy Commission of Nigeria
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EEEP	ECOWAS Energy Efficiency Policy
EER	Energy Efficiency Ratio
EEDC	Enugu Electricity Distribution Company
EEl	Energy Efficiency Index
EIA	Energy Information Agency

EnSM	Environmentally Sound Management
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
EPSR	Electric Power Sector Reform
ESEPC	Enugu State Economic Planning Commission
ESG	Enugu State Government
ESRL	Earth System Research Laboratory
EU	European Union
FGN	Federal Government of Nigeria
FME	Federal Ministry of Environment
FMP	Federal Ministry of Power
FMST	Federal Ministry of Science and Technology
GDP	Gross Domestic Product
GEF	Global Environment Facility
GEP	Global Energy Partners
GenCos	Electricity Generation Companies
GHG	Greenhouse Gas
GIZ	Gesellschaft für Internationale Zusammenarbeit
Gt	Gigatonnes
GWh	Gigawatt hours
GWP	Global Warming Potential
HCFC	Hydro chlorofluorocarbon
HFC	Hydrofluorocarbon
Hg	Mercury
ICREEE	Inter-Ministerial Committee on renewable energy and energy efficiency
IEA	International Energy Agency
IEC	International Electrotechnical Commission

IGR	Internally Generated Revenue
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
Km <sup>2</sup>	Square kilometre
KWh	kilowatt hours
kWh/year	kilowatt hours per year
LBL	Lawrence Berkeley National Laboratory
LED	Light Emitting Diode
LGA	Local Government Area
lm/w	Lumens per watt
LUCF	Land-Use Change and Forestry
MAED	Model for Analysis of Energy Demand
MANCAP	Mandatory Conformity Assessment Programme
MDAs	Ministries, Departments and Agencies
MEPS	Minimum Energy Performance Standards
MtCO <sub>2</sub> e	Million tonnes carbon dioxide equivalent
Mtoe	Million tonnes of oil equivalent
MVA	Mega Volt Amp
MVE	Monitoring Verification Enforcement
MW	Megawatt
MWh	Megawatt hours
N <sub>2</sub> O	Nitrous oxide
NACOP	National Council on Power
NBET	Nigerian Bulk Electricity Trading
NCC	National Control Centre
NCEE	National Centre for Energy and Environment
NCEEC	National Centre for Energy Efficiency and Conservation
NDA	Niger Dams Authority

NDC	Nationally Determined Contribution
NEEAP	National Energy Efficiency Action Plan
NEEP	National Energy Efficiency Programme
NEMP	National Energy Master Plan
NEP	National Energy Policy
NEPA	National Electric Power Authority
NEPAD	New Partnership for Africa's Development
NERC	Nigerian Electricity Regulatory Commission
NESP	Nigerian Energy Support Programme
NESREA	National Environmental Standards and Regulations Enforcement Agency
NGN	Nigerian Naira
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
NOO	National Ozone Office
NPC	National Planning Commission
NPC	National Population Commission
NREAP	National Renewable Energy Action Plan
NREEEP	National Renewable Energy and Energy Efficiency Policy
ODP	Ozone depleting potential
ODS	Ozone Depleting Substances
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of the Petroleum Exporting Countries
PAMS	Policy Analysis Modelling System
PES	Primary Energy Savings
PFC	Perfluorocarbon
PHCN	Power Holding Company of Nigeria
PPMV	Parts Per-Million Volume

PS	Policy Scenario
R&D	Research and Development
RQ	Research Question
SCHER	Scientific Committee on Health and Environmental Risks
SEforAll	Sustainable Energy for All
SF <sub>3</sub>	Sulphur hexafluoride
SON	Standards Organisation of Nigeria
SONCAP	Standards Organisation of Nigeria Conformity Assessment Programme
T&D	Transmission and Distribution
TCN	Transmission Company of Nigeria
TWh	Terawatt hours
TFES	Total Final Energy Savings
UEC	Unit Energy Consumption
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UN Environment	United Nations Environment
UNFCCC	United Nations Framework Convention on Climate Change
UNTC	United Nations Treaty Collections
USAID	United States Agency for International Development
US\$	United States Dollars
U4E	United for Efficiency
W	Watts
WBGU	Wissenschaftliche Beirat der Bundesregierung Globale Umweltveränderungen
WEC	World Energy Council
WHO	World Health Organisation

# 1. INTRODUCTION

This chapter focuses on the overall research framework of this dissertation. It provides an insight into the main motivation within which this research was carried out. It will introduce the research background and problem, the objectives, research questions and hypotheses that this research will attempt to unravel. It will also present the scope and limitations of the research and give a brief description of the expected outcome as well as the target audience. This chapter also presents the structural outline of the thesis.

## 1.1 GENERAL STATEMENT

In reference to the revised edition of the National Energy Policy (NEP) developed by the Energy Commission of Nigeria (ECN), annual electricity consumption has increased from 1.273 Gigawatt hours (GWh) in 1970 to 29.573 GWh in 2012 (ECN, 2013b, p. 41). Within the same period (1970 to 2012), World Bank data show that Nigeria's electric power consumption in kilowatt-hour (kWh) per capita<sup>1</sup> increased from 28.6 kWh to 156.7 kWh (World Bank, 2014) (figure 1.1). These figures however, may represent a suppressed demand due to poor accessibility to the national grid (according to the World Bank estimates, about 59.3 % of the total population had access to grid electricity in 2016). This increasing electricity consumption trend is also irrespective of the unreliability of electricity supply (electricity demand outweighs supply; see section 1.1.1) caused by generation and transmission challenges. Available data on electricity consumption by sector in Nigeria shows that the residential sector accounts for over 50 % of final electricity consumption whereas the commercial and industrial sectors have accounted for 25 % each (ECN, 2013b, p. 41). Electricity usage in the residential sector is mainly for lighting, cooling, refrigeration, and other various electrical appliances usage such as television, radio sets and pressing irons. However, lighting and appliances (notably, refrigerators and air conditioners) represent the fastest-growing energy loads in the country and majority of their usage are done using inefficient products (ECN, 2013a, p. 2; ECN 2013b, p. 51). For instance, there is an estimated 500 million incandescent light bulbs (popularly called "yellow bulbs") in the country

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<sup>1</sup> Electricity power consumption per capita (kWh) is equivalent to electricity production by power plants plus imports, less power plants' own use and transmission, distribution and transformation losses, less exports and divided by midyear population (World Bank, 2014).



and also an influx of second-hand or used electrical appliances (Go green Nigeria website). The use of inefficient electrical appliances is associated with high energy consumption and wastage of power generated in the economy with corresponding high emission rates which jeopardize global efforts to lower carbon emission. The ongoing electrification programs and growing population would mean that more households will be connected to the national grid. This might also mean that the use of domestic appliances will continue to grow, which may increase electricity demand and further exacerbate environmental emissions. A United Nations (UN) Inventory indicates that Nigeria accounts for 0.57 % of total global emissions, making Nigeria one of the top 25 emitting nations (Climate scorecard, 2017).

There are number of scientific evidence in literature that demand-side management measures such as energy efficiency are cost-effective means of mitigating the rising trend of electricity demand, improving reliability of electricity supply and reducing greenhouse gas (GHG) emissions and thus, should be mainstreamed in energy system planning and national energy policies (see: Weizsäcker et al., 1998, p. 29; Kushler et al., 2003, p. 12; Letschert et al., 2013, p. 9). For instance, a report by the Community Research and Development Centre (CREDC) (a non-governmental, non-profit organization registered in Nigeria) reveals that energy used for lighting in households in Nigeria can be reduced by almost 67 % if the widely used incandescent light bulbs were replaced by energy-saving bulbs (CREDC, 2009, p. 11).

In acknowledgment of the global call towards tackling climate change, Nigeria has endorsed several regional and international climate and environmental regimes such as the Paris Climate Agreement<sup>2</sup> which demands a commitment to embark on sustainable development. For instance, Nigeria's Nationally Determined Contribution (NDC)<sup>3</sup> to the Paris Agreement demonstrates ambitious pledge to reduce economy-wide GHG emissions. Also, in response to the directives of the Economic Community of West African States (ECOWAS) on the need for improved sustainable economic growth in the region, Nigeria has adopted the UN Sustainable Energy for All (SEforAll) initiative to embark on sustainable and inclusive economic growth while reducing carbon pollution. The obvious challenges involved in expanding generating facilities

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<sup>2</sup> The Paris Agreement builds upon the activities of the United Nations Framework Convention on Climate Change (UNFCCC) and for the first time, gathers all nations into a common goal to initiate ambitious efforts to combat climate change and adapt to its impacts; it also calls for improved support to assist developing countries to achieve this common goal (UNFCCC, 2015; Albrecht, 2016, p. 142).

<sup>3</sup> Albrecht (2016, p. 142) defined NDCs as the main instrument to reach the targets of the Paris Agreement (Art. 4 para 2).

and meeting commitments to global environmental regimes underscore the need to promote energy savings. The government has thus, identified energy efficiency as one of the key measures of reducing emissions and growing electricity demand. A national target of 2 % per year increase in energy efficiency from the base year of 2015 (30 % by 2030) has been established in Nigeria's NDC as part of the nation's commitment to the global effort of reducing GHG emissions. As a result, there has been a growing national interest in establishing policies to redress the present counterproductive trend of electricity consumption and as well, compliment government's effort on improving supply-side capacities since energy saved can be made available to other regions. Part of this program, which is being implemented in partnership with relevant Ministries, Departments and Agencies (MDAs), is the development of Minimum Energy Performance Standards (MEPS) and Energy Labels<sup>4</sup> for the three major energy consuming products (lighting, air conditioners and refrigerators). The impacts of these programs on the growing energy consumption and environmental emissions will depend on the effectiveness of the supporting policies and strategic roles of the relevant institutions in addressing key barriers to the deployment of energy efficiency measures. This will also determine the success of increasing energy efficiency in its key role of achieving the compliance of the pledges reached in Nigeria's NDC.

This thesis, conceptualized as a policy-oriented research, adopts both top-down and bottom-up methods of investigation to identify necessary actions needed to maximize the benefits of increasing energy efficiency in Nigeria; the top-down method examines existing energy efficiency policies and institutional mandates to identify significant regulatory and institutional barriers to the advancement of energy efficiency and the bottom-up method investigates the policy impacts of the newly developed MEPS for light bulbs, refrigerators and air conditioners which is necessary to gain government's commitment to championing energy efficiency and also, to establish a robust baseline for tracking impacts of the MEPS program. The impacts are modeled based on three conceptualized policy scenarios; a scenario that assumes no policy actions, a scenario that takes the current appliance standards into consideration and a scenario that assumes the implementation of a more aggressive policy measure. The identified barriers

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<sup>4</sup> MEPS specify the minimum level of energy performance that an appliance or product must meet or exceed before they can be sold in a market and the energy labels provide consumers with product's energy performance information at point-of-sale which guides consumers purchase decisions.

would be necessary to reveal possible areas of policy interventions and institutional activities necessary for the widespread diffusion of energy efficiency. Evaluating the policy impacts (under the conceptualized scenarios) will provide empirical findings necessary for presenting a case for energy efficiency, identify capacities for improvement of current standard (which is necessary to advise policy design of future MEPS programs), setting feasible energy-saving goals and planning for program evaluation.

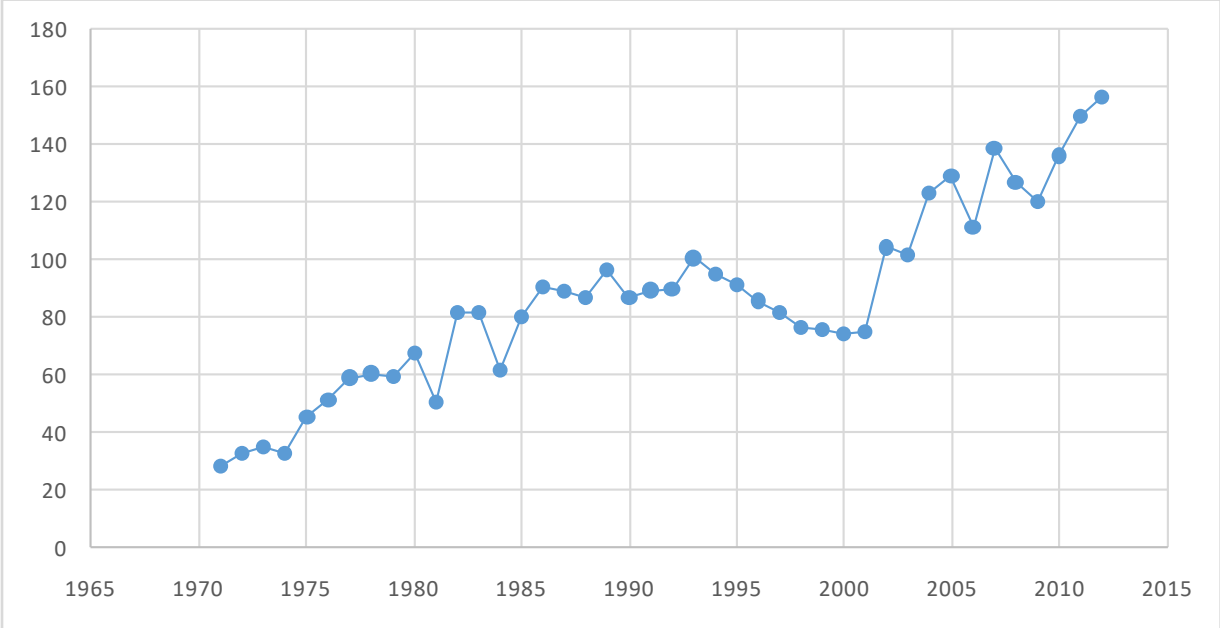


Figure 1.1 Electric power consumption (kWh per capita) in Nigeria (Data source: Based on World Bank (2014) historical data).

**1.1.1 NIGERIA ELECTRICITY SECTOR DEVELOPMENT, CURRENT STATUS AND CHALLENGES**

Power generation in Nigeria has evolved over the years. The Electricity Corporation of Nigeria (ECN) was established by an Act of Parliament in 1951. Likewise, the Niger Dams Authority (NDA) was also established in 1962 for the development of hydroelectricity power. These two companies were merged in 1972 to form the National Electric Power Authority (NEPA). The NEPA had the sole responsibility for the generation, transmission and distribution of electricity in the country. According to the report of the “Deutsche Gesellschaft für Internationale Zusammenarbeit” (GIZ), about 77 % of Nigeria's electricity production is thermal-based (mostly natural gas) and 23 % hydro (GIZ, 2013, p. 14). Due to several challenges, notably, shortage in gas supply and inadequate gas transmission pipelines, the grid has continuously performed below installed capacity. Also, because of the inefficient grid infrastructure, the wheeling

capacity of the grid is not sufficient enough to transmit generated electricity. Expansion of installed generation capacity is not simultaneously followed-up with a strategic transmission and distribution systems expansion. In reference to the online report of the Nigerian Electricity Regulatory Commission (NERC), the grid has a current transmission wheeling capacity of 5,300 MW; even though this is higher than the average operational generation capacity of 3,879 MW, it is still very far below the total installed generation capacity of 10,396 MW<sup>5</sup> (NERC online).

To address these challenges and improve reliability and efficient supply of electricity, the federal government has commenced major power sector reforms. The Electric Power Sector Reform (EPSR) Act was enacted in 2005 to encourage private sector participation in the electricity sector. The Act initially led to the restructuring of NEPA to form the Power Holding Company of Nigeria (PHCN) (established to take responsibility of power generation, transmission and distribution in the interim). Subsequently, the Act further saw to the unbundling of the new PHCN and provided the legal basis that enabled private sector participation in electricity generation and distribution. The PHCN was unbundled into eleven privately-owned electricity distribution companies (DisCos)<sup>6</sup> and six generating companies (GenCos)<sup>7</sup> while the federal government manages electricity transmission through the newly created Transmission Company of Nigeria (TCN) (NERC online). The Nigerian Bulk Electricity Trading (NBET) Plc is responsible for buying electricity from the GenCos and selling it to the DisCos. Within this power purchase structure, the DisCos pay NBET for electricity received from the GenCos and then NBET pays the GenCos for the electricity transmitted into the grid. The end-users pay the DisCos for electricity consumed and the end-user tariff depends on the customer category (that is, private, commercial or industrial user) (GIZ, 2013, p. 96). The National Control Centre (NCC) which is currently part of the TCN controls the frequency and maintains grid reliability and stability.

Despite the impressive efforts at the power sector reforms, the transformation of Nigeria's power sector remains a huge challenge as erratic power supply persists. According to the GIZ report, the inadequate supply of electricity has been identified as the most important factor affecting investment and sustainable economic growth in Nigeria (GIZ, 2013, p. 15). It has also

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<sup>5</sup> Out of the total installed capacity of 10,396 MW, thermal based generation has a total installed capacity of 8,457.6 MW and hydropower based generation have a total installed capacity of 1,938.4 MW (NERC online).

<sup>6</sup> The eleven DisCos are the Enugu Distribution Company, Kaduna, Kano, Yola, Jos, Abuja, Ibadan, Ikeja, Eko, Benin and Port Harcourt (NERC online)

<sup>7</sup> The GenCos are the Afam Power Plc, Sapele Power Plc, Egbin Power plc, Ughelli Power Plc, Kainji Power Plant, Jebba Power Plant and Shiroro Power Plc (NERC online)

been estimated that Nigeria lost about 1 % of her GDP in 2008 due to energy crisis (Nigeria Country Report, 2014). Furthermore, based on estimates of the ECN cited in GIZ (2013), electricity demand will continue to grow. Assuming a 13 % annual GDP growth rate, national electricity demand will increase to 297,900 MW in 2030 from 5,746 MW in the base year of 2005 and meeting this demand will require an annual improvement in supply-side capacity by 11,686 MW (GIZ, 2013, p. 15). In addition, as part of national economic transformation agenda, the Nigeria vision 20:2020<sup>8</sup> targets to launch the country as one of the top 20 economies in the world; and it has been estimated that, for Nigeria to attain this goal, electricity generation capacity will be at 35,000 MW by 2020 (National Planning Commission, 2009, p. 14; NERC online). Considering the current grid generation capacity of 3879 MW, it means that by 2020, Nigeria might need to increase electricity generation by approximately nine-fold.

A shift to energy efficiency could contribute to reducing economy-wide energy consumption and bridging the electricity supply-demand gap in an environmentally friendly way. This would reduce the need for the construction of new power generating facilities to sustain economic transformation; thus, decoupling economic growth from energy consumption. As a result, it is no longer whether Nigeria should embark on electricity end-use efficiency but rather, how and to what extent can electricity end-use efficiency assist in stabilizing electricity demand and contribute to alleviating electricity supply challenges.

### **1.1.2. EVOLUTION OF ENERGY EFFICIENCY POLICIES IN NIGERIA**

The National Energy Policy (NEP) of 2003 introduced the basis for energy efficiency in Nigeria. The NEP was developed and implemented by the Energy Commission of Nigeria (ECN). The NEP sets a national target of 75 % electrification rate by 2020 (ECN, 2003, p. 36). It highlights the need for electricity mix diversification and identifies renewable energy and energy efficiency as a form of energy resource towards the realization of the national target in a sustainable way (ECN, 2003, p. 8). The National Energy Master Plan (NEMP) developed in 2007 stipulates the implementation framework for the NEP. The NEMP provided implementation strategies for all

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<sup>8</sup> The Nigeria vision 20:2020 targets to launch Nigeria as one of the top 20 economies in the world by 2020 with a gross domestic product (GDP) of 900 billion United States Dollars (USD) and per capita GDP of USD 4000; the vision 20:2020 highlights that for Nigeria to attain this target, the economy must grow at an average of 13.8 % between the time horizon of 2009 to 2020 (National Planning Commission, 2009, p. 9).

energy resources considered in the NEP. The NEMP also addressed the issue of energy utilization and the establishment of energy data bank.

The recognition of the fact that energy utilization in all sectors of the economy is far from being efficient, led to the development of the revised version of the NEP in 2013. The NEP 2013, highlights three major implications of inefficient use of energy to the economy to include; excessive investments in improving electricity supply infrastructure more than what would have been required if electricity is used more efficiently, increased environmental emissions and high energy content of goods manufactured in Nigeria (ECN, 2013b, p. 55). The revised version of the NEP, therefore, underscores the need to emphasize on the effective and efficient use of energy in the economy and proposes the following major sectors to focus on for energy efficiency and conservation: residential sector, commercial sector, industry, transport and agricultural sectors (ECN, 2013b, p. 54). Furtherance to the federal government's initiative to diversify the nation's energy mix, and enhance the efficient use of energy in the economy, while providing affordable and reliable electricity in sustainable manner, an inter-ministerial committee on renewable energy and energy efficiency (ICREEE) coordinated by the Federal Ministry of Power (FMP) and comprising of key MDAs in the energy sector was constituted and charged with the mandate to produce the first ever national policy on renewable energy and energy efficiency. This resulted in the development of the National Renewable Energy and Energy Efficiency Policy (NREEEP) which was finalized in 2015. The NREEEP served as government's overarching policies geared towards removing major regulatory and institutional barriers against the uptake of renewable energy and energy efficiency in Nigeria. The NREEEP required the ICREEE to produce the national energy action plans within six to twelve months of the approval of the NREEEP.

ICREEE with the collaboration of the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) has developed the National Energy Efficiency Action Plan (NEEAP) and the National Renewable Energy Action Plan (NREAP). ECREEE's involvement in the project is consistent with the commitment of the regional body to assist member states in delivering affordable and reliable supply of energy in their economies within the UN SEforAll initiative. The NEEAP champions energy efficiency as a resource and stipulates actions to mitigate the impacts of the use of inefficient appliances on the grid load. It is expected that this will redress the inefficient use of energy in the economy and enhance grid operational efficiency.

The action plan consolidates the development of MEPS for electrical products. Nigeria has been developing MEPS and energy efficiency labels since 2012. MEPS is being developed with the assistance of ECREEE and various international organizations. So far, MEPS has been developed for compact fluorescent lamps (CFLs), air conditioners and refrigerators. The regional standard harmonization initiative is accelerating the harmonization of appliance standards within the ECOWAS region. In Nigeria, the harmonization initiative has resulted in adopting lighting standards that conform to the regional specifications and the harmonized standards for refrigerators and air conditioners will be domesticated once it is approved by the Nigeria Standards Board. However, it is important to mention that the regional or ECOWAS standard (ECOSTAND) for refrigerators and air conditioners is identical to the developed standards in Nigeria (SON, 2015, p. 2).

## **1.2 PROBLEM FORMULATION**

### **1.2.1. ENERGY-RELATED CHALLENGES**

In Nigeria, energy efficiency regulations (MEPS and Energy Guide Labels) have been developed to address national energy and emissions related challenges and to achieve an energy-efficient appliance market transformation. These include:

- To mitigate the growth in electricity consumption of appliances thereby reducing electricity demand and bridging electricity supply-demand gap and consequently, lowering the need to invest in new grid infrastructures.
- Ensure the removal of inefficient appliances from the market and the supply of only efficient products.
- Provide information to consumers on the relative energy consumption levels of products which will assist them in making appropriate purchase decisions.
- Reduce consumers' energy bills associated with the use of inefficient appliances which in turn exerts unnecessary pressure on the national grid.
- Reduce GHG emissions and assist the country to meet various regional and international climate and environmental commitments.
- Ensure that regulations remain effective and appropriate over time.

The local distribution company at Enugu (Enugu Electricity Distribution Company – EEDC) is responsible for electricity distribution in 18 districts including Enugu urban metropolis. It

receives a daily electricity allocation of 9 % of the total generated power available on the national grid. This allocation amounts to an average of 400 MW to 500 MW. Average electricity demand for the connected users within the entire district is 850 MW. This leaves a shortage of between 350 MW to 450 MW. Specifically, the average electricity demand for Enugu urban metropolis is in the range of 100 – 110 MW out of which an average of 65 MW is available for distribution, which leaves a deficit in the range of 35 MW to 45 MW. Furthermore, about 10 % of the allocated electricity is lost due to poor and inefficient grid transmission lines (EEDC interview response). EEDC has embarked on some demand- and supply-side measures to help address challenges of inadequate electricity supply. These include the ongoing free distribution of pre-paid meters (expected to instill energy management behaviors in consumers as they become more conscious of their electricity consumptions), network improvement, installation of power transformers. As presented above, the electricity supply-demand gap could be exacerbated due to the expected increase in electricity demand arising from population growth, electrification programs and possible improvement in living standards as a result of anticipated economic growth. Based on interview responses, EEDC at the moment is not engaged in any MEPS support program as a means of improving the reliability of electricity supply or complementing the expected impact from the widespread installation of pre-paid meters. Presently, utilities in Nigeria are not mandated by law to engage in any form of energy efficiency program. Utility engagement in energy efficiency programs could improve their operational efficiency.

The long history of focusing only on increasing supply-side capacity in electricity generation in Nigeria and not recognizing demand-side measures such as energy efficiency as a form of energy resource, locks-in energy policies into fossil fuel-based energy systems which might present challenges to gaining full government support to advance energy efficiency. Scientific results or empirical findings (such as identified policy impacts of increasing energy efficiency) is needed to spur government's actions towards taking a bold step in creating appropriate legislative and institutional capacity to enforce energy efficiency related policies and hence, overcome existing locked-in policy directions (see: Unruh, 2002, p. 321).

If government's decision is not adequately taken on time, great opportunity to promote a future energy-efficient appliance market and its expected benefits will be lost. Investigating the actual



potential of MEPS in mitigating energy supply challenges would examine to what extent end-use energy efficiency regulations contribute to alleviating electricity supply-demand gaps and to reducing emissions especially, in respect to the established targets in Nigeria's NDC. There is limited research in this area. The research conceptualized three scenarios to investigate the impact of the developed appliance standards on alleviating energy-related challenges. These scenarios will help to design solutions and also, understand the impact of the solutions as it relates to realizing the national aims of implementing appliance standard regulations in Nigeria.

### **Regulatory scenarios to study identified problems.**

The following policy scenarios have been conceptualized to study the identified problems:

- Option 1: Business-as-usual (BAU). This option would see no changes to the current situation. Implementation and/or enforcement of the established MEPS would largely remain at an undesirable level. However, it can be expected that there will be marginal improvements in energy efficiency of products supplied in the Nigerian market. These improvements could be logically supported due to the presence of MEPS in countries from which most of the appliances are imported into Nigeria. Most of the appliance producing nations has appliance regulations in place for units sold in their markets but appliances for external markets are most often not regulated by the producing nation's local MEPS. The presence of regulations in the importing nation like Nigeria will ensure that only appliance meeting established standards are allowed into the country. Without these regulations, importers will end up importing products of low efficiency level to maximize their profits. Consequently, efficiency improvements are likely to be slow under this scenario due to the poorly regulated market.
- Option 2: Implement and enforce current MEPS. This option would require Nigeria to effectively pursue the implementation and/or effective enforcement of developed MEPS. It is expected that the implementation and enforcement of the current MEPS would assist in addressing national energy and emissions related challenges. It will also ensure the saturation of the Nigerian appliance market with efficient products so that consumers can purchase appliances that are both affordable and consumes less energy. However, energy and emission savings will only be at the rate achievable with the present regulatory standards.

- Option 3: Develop and implement more aggressive MEPS. In addition to enforcing the MEPS as discussed in option 2, option 3 would involve developing and implementing higher MEPS levels for appliances based on best available technologies (BAT). BAT levels are characterized by product designs aimed at achieving higher energy efficiency. This scenario was conceptualized based on the call by the United Nations Framework Convention on Climate Change (UNFCCC) for Parties to the Paris Climate Agreement to ensure the full implementation of their NDCs as they are, and also, to significantly and progressively, increase the level of ambition of individual mitigation measures as a means of continuous global efforts to stabilize GHG emissions (Art. 3 of the Paris Agreement). This assertion is substantiated in a recent report by Munzinger et al. (2016, p. 10) which states that, even if the composition of all NDCs were to be fully implemented, it would not be enough to limit the global temperature rise to 2°C. This scenario will then examine the existing potential for the improvement of the current standards and estimate the magnitude of impacts a more stringent MEPS will have on energy consumption and emissions reductions.

### **1.2.2 BASELINE DATA**

The important first step in developing an effective energy efficiency policy is conducting a market analysis to determine major energy consuming appliances and the range of efficiency levels of these products on the target market. It also provides a robust background against which the potential impact of new policy actions can be evaluated (Letschert, et al., 2015, p. 2). Such detailed baseline studies are used to set energy performance levels and usually, are the foundation for planning energy efficiency policies and actions (Asian Development Bank, 2015, p. 6). The baseline assessment has also become an available source for product information (Letschert, et al., 2015, p. 4). Important product's information includes; detailed product features and characteristics such as prevalent sizes and volumes of refrigerators on the target market and corresponding baseline efficiency levels, air conditioner baseline cooling capacities and energy efficiency ratios (EER), product brand and manufacturer, annual stock, sales or shipments, product origin (locally produced or imported). The resulting database would give a detailed and robust picture of Nigeria's appliance market and would provide a source of information for research in the area of appliance energy efficiency. The lack of market data has

been identified as a major impediment to the establishment of a rational and effective policy measure to address appliance energy demand on a target market because there will not be enough information to guide program design such as MEPS and energy labels and no background to monitor or track the impact of that program in reference to a robust baseline (Letschert et al., 2015, p. 2). The draft end-use metering campaign report (2013) by the Energy Commission of Nigeria (ECN) is the only baseline study that examined the current baseline level of household electricity consumption. It assessed the baseline energy efficiency of the main household electrical appliances (ECN, 2013a, p. 7).<sup>9</sup> The study is an empirical effort to collect baseline information that will guide the setting of MEPS for selected appliances (lighting, refrigerators, and air conditioners). However, the analysis did not provide very important details on appliance features and characteristics as enumerated above, which may present a source of concern on its capacity to inform the design of an appropriate appliance standard. It is also expected that the data from this metering report would serve as a means to campaign for energy efficiency from Nigerian policy makers and legislators to achieve the desired policy change. However, the study did not take into consideration baseline energy end-use projections and thus, did not delve into identifying or estimating possible end-use energy savings potential. End-use specific energy savings potential is necessary to establish a case for energy efficiency and to design policies that target end-use applications with huge emission saving possibility. It may be doubtful if the metering study has enough analytical information of statistical significance to establish energy saving goals; and as well, not enough details to campaign for political support from the law makers especially in a region with a long history of energy policy that focuses mainly on improving supply-side capacity powered by fossil fuel-based energy sources.

### **1.2.3 ENERGY SECTOR AND CLIMATE CHANGE**

The increasing demand for energy worldwide has constituted a major challenge to actions geared towards climate protection. Based on the report of the Intergovernmental Panel on Climate Change (IPCC) CO<sub>2</sub> emissions from fossil fuel combustion has been on the increase

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<sup>9</sup> The end-use metering report was necessitated as a result of the overall project, by ECN and the Nigeria Federal Ministry of Environment (FME) in collaboration with the United Nations Development Programme (UNDP) and the Global Environmental Facility (GEF), to reduce energy demand in Nigeria and thus, increase access to electricity and minimize greenhouse gas (GHG) emission from energy generation.

mainly due to rise in population and economic growth (IPCC, 2014a, p. 5). Globally, there has been growing support for energy efficiency as an energy resource and a means of reducing environmental emissions. Consequently, effective energy efficiency policy making is becoming increasingly vital among policy makers.

Reports on the World Resources Institute (WRI) website show that in 2014, total GHG emissions in Nigeria, including Land-Use Change and Forestry (LUCF), is 492.44 MtCO<sub>2</sub>e and the energy sector emission contribution stands at 160.70 MtCO<sub>2</sub>e (WRI, 2014), which represents about 33 % of total GHG emissions and the second most GHG emitting sector after LUCF. The report further indicates that electricity and heat generation accounted for approximately, 15 % (23.50 MtCO<sub>2</sub>e) of total emissions in the energy sub-sector.

Climate protection measures should engage key sectors such as the energy sector in policy planning in order to reach expected goals and commitments to international agreements. This calls for the need to create necessary awareness, not just for consumers, but also among policy makers on the need to mainstream energy efficiency in Nigeria's energy policy and underscores the significant role of effective policy design and implementation in eliminating major barriers against successful energy efficiency deployment which creates energy efficiency gaps.

### **1.3 A CASE FOR ENERGY EFFICIENCY STANDARDS**

#### **1.3.1 ENERGY EFFICIENCY FOR GREENHOUSE GAS MITIGATION**

The IPCC defines climate change as, "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer" (IPCC, 2014b, p. 39). The IPCC highlights that the change in climate is due to natural internal processes such as volcanic eruptions and persistent anthropogenic alterations in the make-up of the atmosphere or in land use (IPCC, 2014c, p. 5). It is now, no longer considered a mystery that the earth is warming partly due to anthropogenic activities, which leads to greenhouse gas (GHG) emissions into the atmosphere.<sup>10</sup> Report of the IPCC reveals that, from a pre-industrial level of 280 parts-per-million by volume (ppmv) around the year 1750, atmospheric carbon dioxide (CO<sub>2</sub>) has

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<sup>10</sup> Greenhouse gases as listed in Annex A to the Kyoto Protocol are: Carbon dioxide (CO<sub>2</sub>); methane (CH<sub>4</sub>); nitrous oxide (N<sub>2</sub>O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulphur hexafluoride (SF<sub>6</sub>); Nitrogen trifluoride (NF<sub>3</sub>); chlorofluorocarbons (CFCs); and hydrochlorofluorocarbons (HCFCs) ([http://unfccc.int/kyoto\\_protocol/doha\\_amendment/items/7362.php](http://unfccc.int/kyoto_protocol/doha_amendment/items/7362.php)).

increased progressively to 367 ppmv in 1999 (IPCC, 2001, p. 39); an augment of about 31 %. Recent online data from the Earth System Research Laboratory (ESRL) of the National Oceanic and Atmospheric Administration (NOAA)<sup>11</sup> show that atmospheric CO<sub>2</sub> has reached a concentration of 408.71 ppmv in July 2018 (NOAA, 2018). Information from the NOAA reveals that the first continuous measurement of atmospheric CO<sub>2</sub> was made in March of 1958 and this has led to understanding the relationship between the increasing levels of atmospheric CO<sub>2</sub> and anthropogenic activities (NOAA, 2018). The CO<sub>2</sub> emission from the combustion of fossil fuel and industrial processes contributed about 78 % of the total GHG emissions within the period 1970 to 2010 (IPCC, 2014a, p. 5).<sup>12</sup> Rising level in the concentration of GHGs in the atmosphere leads to global warming which invariably causes climate change.<sup>13</sup> Based on observed changes in the atmospheric global mean temperature between the period 1986 to 2015, the global mean surface temperature change for the period 2016 to 2035 is estimated to be in the range 0.3–0.7 degree Celsius (°C) (IPCC, 2014a, p. 10). The continuation of the past trends BAU of anthropogenic activities will further exacerbate atmospheric temperature in the twenty-first century (IPCC, 2014a, p. 10). An increase in global warming above the mean temperature of 2°C would have irreversible, highly uncontrollable consequences for both human beings and ecosystems (IPCC, 2018, p. 7).<sup>14</sup> Total CO<sub>2</sub> emissions from human activities between the year 1750 and 2011 were 2040 ±310 GtCO<sub>2</sub> and 40 % of this has already accumulated in the atmosphere and the oceans have absorbed about 30 % leading to acidification of the ocean (IPCC, 2014a, p.

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<sup>11</sup> The NOAA is an agency under the United States Department of Commerce that is committed to research geared towards understanding changes in climate, weather, oceans and coasts; the agency provides monthly monitoring on changes in the atmospheric CO<sub>2</sub> concentrations (NOAA, 2018).

<sup>12</sup> CO<sub>2</sub> a major by-product of fossil fuel combustion and forest clearance has been linked, together with other GHGs, as being responsible for the current global warming. CO<sub>2</sub> remains the main anthropogenic GHG, accounting for 76 % of overall anthropogenic GHG emissions in 2010, 16 % from CH<sub>4</sub> and 6.2 % from N<sub>2</sub>O and 2.0 % from fluorinated gases (IPCC, 2014d, p. 6).

<sup>13</sup> Information retrieved from the official website of the United States Environmental Protection Agency (EPA) reveals that the capacity of each GHG to cause global warming depends on its global warming potential (GWP) which in turn depends on its radiative efficiency (ability to absorb heat) and their lifetime (how long they stay in the atmosphere) (Available online at: <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>) (last accessed on: 30.05.2019). The EPA official website defines GWP as the measure of the amount of heat the emission of 1 ton of a gas will absorb over a given time period (usually, a 100 years), relative to the emission of 1 ton of CO<sub>2</sub>. GWP provides a common unit of measure (carbon dioxide equivalents: CO<sub>2</sub>-equivalents). The GWP for GHGs, considering a 100 years lifetime, are: carbon dioxide = 1; methane = 28-36; nitrous oxide = 265-298; and sulphur hexafluoride = 22800; HFCs, HCFCs, PFCs consists of large number of different gases that have high GWPs (EPA official website).

<sup>14</sup> Noticeable impacts of climate change include: rising sea levels, increased extreme weather effects such as destructive hurricanes, severe floods, monstrous tomadoes, incessant droughts and desertification, increased loss of biodiversity and acidification of oceans.

4).<sup>15</sup> In reference to Munzinger, et al., (2016, p. 3), some GHGs even pose more threat to the environment due to their huge potential to warm the earth and/or their high ability to deplete the ozone layer. GHGs such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), which fall under this category, are mainly used as refrigerants in cooling systems like refrigerators and air conditioners (Munzinger, et al., 2016, p. 3). Increasing population and rise in ambient temperature would drive a growing demand for cooling products which may exacerbate the release of these gases with high global warming and ozone depleting potentials into the environment. Likewise, depending on the energy source for electricity generation, the use of these appliances will also contribute, indirectly, to CO<sub>2</sub> emissions through electricity consumption.

In the continuation of efforts to mitigate the increasing amount of CO<sub>2</sub> and other GHGs in the atmosphere and thus, chart a new course in the global climate campaign, the international community has convened various international conventions and reached several multilateral agreements, with set global goals, which are geared towards the protection of the environment. A review of these multilateral agreements (see chapter 7) shows growing support for energy efficiency as a cost-effective means of reducing environmental emissions. It also identifies improvement in energy efficiency as a “High Impact Opportunity” to reduce countries’ GHG emissions and eliminate old appliances that often contain environmentally damaging fluorinated gases as their refrigerant. Consequently, policy makers are mandated to design and implement economy-wide and sector-specific regional and/or national energy efficiency mitigation strategies, build enabling institutional structures towards achieving global climate targets and to report success achieved.

### **1.3.2 ENERGY EFFICIENCY FOR GREENHOUSE GAS MITIGATION – NATIONAL CONTEXT**

Energy efficiency, especially for end-use products, is increasingly becoming an important aspect of any government’s portfolio not only for energy-performance improvements but also for climate change mitigation measure. According to the Collaborative Labeling and Appliance

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<sup>15</sup> Information retrieved from the Smithsonian Institute’s official website explains that when CO<sub>2</sub> dissolves in the ocean, the ocean’s pH drops which make it acidic and small changes in the pH level of seawater can have harmful effects on marine life (impacting reproduction and growth). Available online at: <https://ocean.si.edu/ocean-life/invertebrates/ocean-acidification> (last accessed on 04.06.2019).

Standards Program (CLASP)<sup>16</sup>; measures (voluntary and/or mandatory) that enhance the market diffusion of cost-effective, energy-efficient products, need to be developed by governments (CLASP, 2005, p. 11). Energy efficiency labels, MEPS for appliances and lighting products with other complementary or supporting measures deserve to be among the first policy tools considered by a country's energy policy makers (CLASP, 2005, p. 11). The development and implementation of energy-efficiency program (such as labels and MEPS) needs, among others, legal, analytical and institutional resources (CLASP, 2005, p. 21). Each of these resources should already be in existence in every nation, and there is a likelihood that, each may also need to be enhanced or strengthened to facilitate effective energy efficiency policy uptake.

Nigeria has joined global efforts in advancing energy efficiency and is at an early stage of development and implementation of an energy efficiency plan. It has issued quite ambitious energy and emission savings targets and has highlighted economy-wide key mitigation strategies to realize these targets (see table 1.1). It is projected that, in the absence of these key mitigation measures, emissions will grow to 900 million tonnes of carbon dioxide equivalent (MtCO<sub>2</sub>e) by 2030 (Nigeria NDC Report, p. 3).<sup>17</sup> However, it is estimated that the implementation of these measures will result to 476 MtCO<sub>2</sub>e GHG emission reduction with improvement in economy-wide energy efficiency measures contributing about 38 % of the estimated total GHG reductions (see table 1.1). Also, the implementation of economy-wide energy efficiency measures is expected to reduce economy-wide energy demand from 180 million tonnes of oil equivalent (Mtoe) to 90 Mtoe in 2030 (Nigeria NDC report, 2017, p. 14). Efforts have been made by relevant government institutions to develop energy efficiency policies and actions for the residential, commercial and industrial sectors. Furthermore, there has been the establishment of appliance standard test centers in designated areas within the country. These energy efficiency actions are expected to contribute to delivering the projected national energy and emission reduction targets (in compliance with the Nigeria's NDC) and to meet various obligations to binding international environmental agreements to which Nigeria is a signatory more especially, those conventions that address GHG emissions and environmental concerns resulting from the use and disposal of end-use electrical appliances (see chapter 7).

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<sup>16</sup> CLASP is an international non-governmental organization (NGO) working on accelerating global best practice appliance energy efficiency policies and market transformation initiatives.

<sup>17</sup> This emission projection assumes a consistent 5 % annual economic growth rate and a 2.5 % annual population growth rate (Nigeria NDC Report, 2017, P. 9).

On the grid, energy-efficient appliances could contribute to the reduction of peak energy demand, saving costs for the government, utilities and consumers; thus, bolstering economic and energy security. Operational efficiency and effectiveness of utilities may also improve due to enhanced energy efficiency.

Table 1.1 Key GHG mitigation strategies

<b>Measure</b>	<b>Potential GHG reduction (million tonnes per year in 2030)</b>
Economy-wide energy efficiency	179
Efficient gas power stations	102
Ending of gas flaring	64
Climate friendly agriculture	74
Reduce electricity transmission losses	26
Renewable energy	31

Source: Nigeria NDC Report, 2017, p.3.

#### **1.4 AIM AND OBJECTIVES OF THE STUDY**

This research is initiated to contribute to knowledge on effective energy efficiency policy planning (in respect to achieving the expected role of energy efficiency in the Nigeria’s NDC). Specifically, the study aims to evaluate the possible energy savings potential associated with the implementation of energy efficient technologies in residential households in Enugu, Nigeria (section 1.6.1 explains the significance of the choice of Enugu for the research). The study particularly focuses on assessing the role of the three identified appliances in achieving energy efficiency in dwellings.

In achieving this aim, the study hopes to accomplish the following objectives:

1. To examine current baseline energy end-use and appliance ownership patterns in different types of regular housing units with varying household characteristics.
2. Establish energy use projections of these appliances in the absence of regulatory standards and examine possible policy impacts from the implementation of current developed MEPS program for light bulbs, refrigerators and air conditioners and the potential impacts of more stringent standards for the reviewed products (the current standards covers only the listed products presently).



3. Assess the capacity of the existing institutional mandates to realize potential savings and identify possible areas of overlaps and gaps in mandates.
4. Evaluate the appropriateness of the existing appliance energy efficiency policies in championing end-use energy efficiency in Nigeria using the integrated policy approach.
5. Identify key barriers at the household levels militating against the diffusion of energy-efficient products in the case study area and develop a tailor-made policy framework, based on best practices, for the advancement of appliance energy efficiency.
6. Examine to what extent the developed MEPS would help local utilities to bridge electricity supply-demand gaps.

### **1.5 RESEARCH QUESTIONS.**

To address the objectives, the following research questions were developed:

1. What are the use patterns and trend of appliance ownership in the case study area?
2. Considering the appliances under review, how much residential energy and emissions savings can be achieved in the short- to medium-term with the implementation of current standards?
3. Are the existing policy measures and institutional roles effective to deliver very significant improvements in energy efficiency?
4. What are the key challenges against the promotion of end-use energy efficiency in Nigeria and the possibilities of overcoming these obstacles?
5. How does energy saving potential study advice energy policies and its role in creating the political will to change a persistent policy direction?

The significance of the research objectives and the research questions can be viewed from the hypothetical benefits linked to improved energy efficiency.

### **1.6 RESEARCH HYPOTHESES.**

To approach the research questions, several hypotheses were developed which will serve as a starting point for further investigations. These hypotheses were developed as a result of the numerous benefits attributed to energy efficiency (theory-based expectations).

1. Energy efficiency enhances economic and sustainable development.
2. With legal framework and enforcement rules, energy efficiency can achieve significant energy and emission savings.

3. A detailed potential study is essential to establish policy impacts of energy efficiency programs which will guide the setting of appropriate energy savings and climate goals.
4. Energy efficiency can be used to mitigate electricity supply reliability issues and thus, improve access to clean and affordable energy.

### **1.7 SIGNIFICANCE OF THE RESEARCH**

The effective design and implementation of energy efficiency policy in Nigeria would contribute to improving the reliability of electricity supply and thus, would complement government's effort on improving supply-side capacities. Since every kilowatt-hour (KWh) of electricity saved by the use of a more efficient appliance translates to a KWh that is available for other users, or as well, a KWh that needs not to be generated. Consequently, it saves cost for capital intensive grid expansion projects which can be channeled into other developmental projects. Implementing effective energy efficiency policies will save end-use energy costs for consumers resulting in having more money to spend in the economy. It will also reduce the energy intensity of goods manufactured in Nigeria, lowering production cost and thus, improving the international competitiveness of goods manufactured in Nigeria. The implementation of effective energy efficiency measures will enhance awareness on the need for efficient appliances and consequently, improve the market for energy-efficient appliances which enhances sustainable and inclusive growth. Effective energy efficiency policy measures also play significant roles in attaining national climate goals and achieving commitments to binding international environmental conventions. International investors consult a country's energy policies as a guide to clean development investment opportunities. The Energy Commission of Nigeria (ECN), which is the Federal Government Institution responsible for energy-related research and energy sector policy formulation and strategic planning, has already in place, the revised National Energy Policy (2013) and the National Energy Master Plan (ECN, 2013b; ECN, 2014) which stipulates the following policies for improving energy efficiency and conservation:

- i. To adopt and promote energy efficiency and conservation best practices in the exploration and utilization of the nation's energy resources.
- ii. Mainstream energy efficiency and conservation best practices in all sectors of the economy.

- iii. To build capacity of the relevant agencies/organizations to develop and enforce policies and regulations (Minimum Energy Performance Standards) to promote energy efficiency best practices.

The effectiveness of the above statements in enhancing the diffusion of efficient appliances in Nigeria in order to reduce energy consumption and achieve significant emissions savings will depend on the political will to create strong institutional and regulatory framework for energy efficiency and also, the design and implementation of appropriate energy efficiency programs and policy instruments commensurate to international best practices and targeted at verified and prospective energy savings potential. To design an effective and appropriate energy efficiency policy or programs for major electrical appliances in Nigeria, there is a need for empirical research to look at the existing and planned policy measures and institutional structures and an assessment of energy saving potentials and current practices. Such empirical findings are also necessary for estimating program budgets, program impact evaluation, review of existing standards and targets and identifying key barriers against expected program outcomes. Assessment of potential impacts of standards is part of the general approach to effective implementation of appliance standards (Constantine et al., 1999, p. 2). There is limited research in this sphere which underscores the innovativeness of this study. This assertion can be substantiated by a United Nations Development Program (UNDP) report (2015) which states that the only studies that have been conducted on energy efficiency are mainly focused on baseline evaluation to understand efficiency levels in Nigeria. These studies include the End-use Monitoring Study in Residential and Public Buildings (2013) by the Energy Commission of Nigeria (ECN), the Nigerian Appliance Inventory Study (UNDP, 2015) and the Nigeria Lighting Compliance Study (Uyigue, et al., 2015, p. 3). Furthermore, information gathered during an interview session with Mr. Etiosa Uyigue, the Project Manager of the GEF-UNDP's Nigeria Energy Efficiency Program (NEEP) (Abuja, 28 September 2017) reveal that no other potential evaluation study was carried out prior to the MEPS development in Nigeria. It is expected that the outcome of this research will provide information that will contribute to strengthening appliance energy efficiency regulatory measures in Nigeria.

### 1.7.1 SIGNIFICANCE OF THE CHOICE OF ENUGU

The unreliability of electricity supply in Nigeria varies across geographic regions. This may be in connection to nearness to the power plants (ECN, 2013a, p. 19). Consequently, some regions may experience more duration of power availability than power outages when compared to other regions. In reference to the metering report of the ECN, the significance of the choice of Enugu as the case study site can be related to its relatively high ratio of power access to power outage when compared to other geopolitical zones (ECN, 2013a, p. 19)<sup>18</sup> (see figure 1.2). The ECN report established a correlation between the average duration of power access per day and annual energy consumption in the studied regions (ECN, 2013a, p. 30). Based on the analysis, Lagos which has the highest duration of power access per day is also the area with the highest annual energy consumption. It could be stated that electricity availability may influence consumers' electricity consumption. An appliance that is off for some time due to power failure will not consume the same amount of electricity as an appliance that has been left functioning for a whole period. Thus, a region with a higher probability of power access would present a more analytical structure to study the potential policy impact of a program such as MEPS. From the metering report, Enugu has an average total household electricity consumption of about 3,330 kilowatt-hours per year (kWh/year), following only Lagos (with an average consumption of about 5,000 kWh/year).

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<sup>18</sup> Statistical report of the ECN metering study has the following distribution of power access to power outage respectively for each of the selected six cities that represent the six geopolitical zones in Nigeria: Lagos (South-West zone) 66 %:34 %; Enugu (South-East zone) 64 %:36 %; Abuja (North-Central zone) 63 %:37 %; Benin (South-South zone) 59 %:41 %; Bauchi (North-East zone) 39 %:61 %; Sokoto (North-West zone) 39 %:61 % (ECN, 2013a, p. 19).

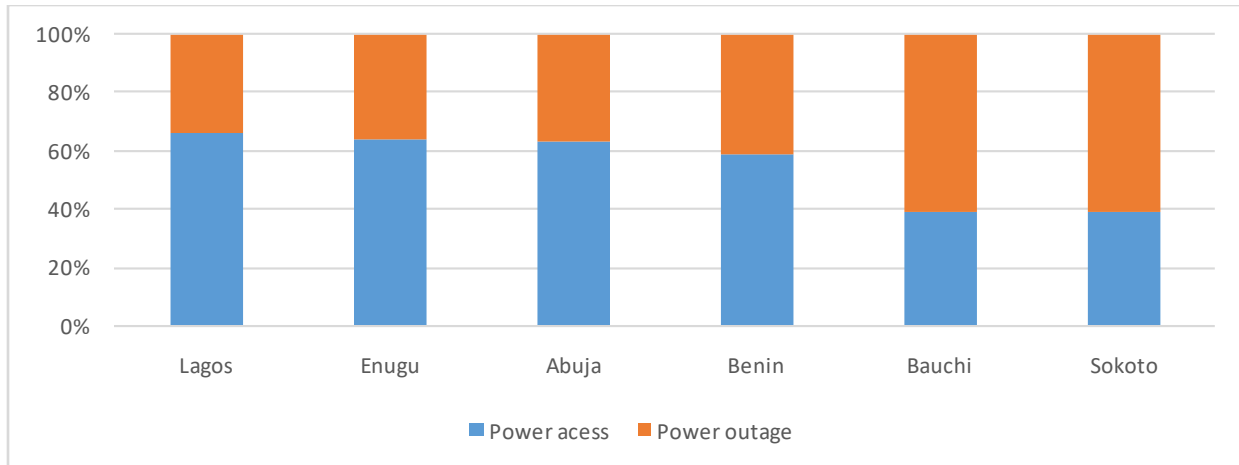


Figure 1.2 Distribution of power access and power outage per studied zone.

Source: based on data from ECN, 2013a, p. 19.

Furthermore, the mild climate and many opportunities of Enugu (South-East Nigeria) attract more residents and investments; resulting in an emerging economic power in the country (see section 4.6). According to the report of the Enugu State Government (ESG), “Enugu State is densely populated, and is rated at 460 persons per square kilometer (km<sup>2</sup>) which is regarded as one of the highest in Africa” (ESG, 2016, p. 8). Based on this presentation and coupled with a growing population, Enugu may be interpreted as a city that could be faced with the challenges of increasing energy or electricity demand in the near future.

### 1.7.2 TARGET AUDIENCE

From the argument above on the significance of the research, it should be observed that the target audience of this research work comprise of various groups. The following paragraphs address these target groups.

In respect to policy and decision makers, this research work aims to provide information that would guide the development process of energy efficiency policies. The outcomes and recommendations produced by this study can aid the design and evaluation of energy efficiency measures in regions where these policy instruments are not yet well established. Furthermore, since energy efficiency addresses the relationship of energy and climate change issues, it is anticipated that this research work would generate significant insight for policy and decision makers that work in the areas of energy and climate policies.

Researchers and scholars interested in the field of energy efficiency improvements and policy design also represent an important target group for this research. The findings enhance

knowledge by analyzing several theoretical and empirical features that are imperative for energy efficiency policy design.

Key stakeholders in the area of energy efficiency form part of the target audience of this dissertation. The detailed review of the institutional and regulatory framework can provide insights into the complexities and dynamics of institutional activities in advancing energy efficiency. It will also emphasize areas where enhanced coordination of activities is needed to avoid overlap and conflict in specific roles.

## **1.8 SCOPE AND LIMITATIONS**

This section enumerates several aspects concerning the defined research boundary and also, discusses those factors that were not within the control of the researcher. Considering the specific aim of this research, the thesis takes its departure from the aspects necessary for the design and implementation of energy efficiency policy.

The research, which falls within the category of technical potential analysis, focuses on reviewing energy saving potential that can be realized through the implementation of energy performance standard regulations. The products under consideration are lighting, refrigerators and air conditioners. These three appliances (lighting, refrigerators and air conditioners) contribute about 50 per cent of energy consumption in households (ECN, 2013a, 40).<sup>19</sup> Technical potential analysis is normally limited by the types of commercially available and emerging technologies that the analyst includes in the analysis (Neubauer, 2014, p. 7). The analysis will not consider the cost-effectiveness of the estimated potential savings. However, outputs from this analysis will serve as inputs into a cost-effectiveness assessment. For instance, the conceptualization of different policy scenarios conducted in the research identified design options or standard levels that could be considered and subjected to a cost-effectiveness screening, with the feasible options that survived the screening analysis considered as potential standard levels based on their life-cycle cost, national and environmental impacts. With Enugu as a case study area, the research identifies key barriers that must be overcome to enhance the widespread use of energy-efficient appliances in regular households in Nigeria. The research

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<sup>19</sup> Relative contribution from the different loads for all appliances in Nigeria (mains: 3,927 kWh/year); Cold appliances 21 % (830 kWh/year); Air conditioner 17 % (677 kWh/year); Light 12 % (454 kWh/year); Cooking 0.4 % (15 kWh/year); Audio visual 3 % (122 kWh/year); Not known 47 % (1,837 kWh/year) (ECN, 2013a, p. 40).

focuses mainly on those appliances that are presently in use in existing buildings. Although respondents were asked to indicate possible appliances they may want to own or buy in the future and factors that may likely influence their decisions. Only households within Enugu urban metropolis were surveyed and these households are all connected to the national grid. The households were drawn from those within the jurisdiction or service area of the only electricity distribution company in the state; Enugu Electricity Distribution Company (EEDC). The research is classified under demand-side energy efficiency measure and thus, did not delve into studying supply-side energy efficiency. Besides, since Nigeria is at an early stage of implementation of energy efficiency regulations, the research did not perform evaluation of policy outcomes. Impacts or ex-post information are crucial for policy evaluation. However, the contextual approach adopted for this research reveals the interdependency between policy design and evaluation. Consequently, even though this thesis focuses on the activities that guide policy design, information from this crucial stage play a significant role by providing baseline information that will be necessary at the policy evaluation stage and as well, for the redesign of programs (Capano and Howlett, 2015, p. 8).

Insufficient data availability, (for instance, the lack of appropriate baseline energy use projections and products features or characteristics), determined largely the extent of analysis, methodological choices and key assumptions. Furthermore, even though relevant stakeholders and government agencies were contacted, not all were willing to provide every required data. However, in some cases, the presentation of the introductory letter from the University soliciting (on behalf of the researcher) for assistance on data collection salvaged the situation. The appliance market in the case study area (and the whole of the country) is quite an open market which is not very organized. This presented some level of challenges in having access to market-related data. Securing and/or scheduling appointments for interviews with relevant government agencies were not without a certain level of restrictions and last minute cancellations. On a particular occasion, the interviewee did not honor the appointment although the researcher traveled hundreds of kilometers to keep to the appointment (in this case, from Enugu to Abuja a distance of about 500 km).

On the consumers' aspect and in some cases, it was a bit difficult to explain the need to use energy-efficient appliance especially considering a region with incessant power outages. Some

of the consumers were of the opinion, “why save energy that is rarely available?” it became quite necessary to explain (most of the times) how the energy saved can actually improve reliability of supply and reduce energy bills. This explanation was in some cases, appreciated. It was also, not possible to personally observe light bulb wattages in all the rooms in a household, such as sleeping rooms. As expected, this is due to restrictions and to respect privacies. However, respondents were asked to observe these themselves and report on the questionnaire. Repeated visits were made in some cases because the head of the household may not be available to answer questions at the initial time of consultation. This may be connected to cultural orientation where the responsibility of providing this information is solely that of the head of the household.

## **1.9 MOTIVATION**

The growing interest in establishing energy efficiency measures in Nigeria spurred the interest of the author of this thesis regarding their design and performance. Nigeria’s economy and population are both increasing rapidly.<sup>20</sup> The economic growth means an improved standard of living for the population and which will have a strong impact on future energy use and emissions. Assuming a high economic growth rate of 13 %, it is estimated that annual electricity demand will rise by 7 % – 13 % (Nigeria country report, 2012; ECN, 2014, p. 11). The projected total electricity demand by the end of the year 2020 at a 7 % GDP growth rate (under a BAU growth scenario) is 45,490 MW (ECN, 2014, p. 11); putting into consideration the current generation capacity of 6,056 MW (NERC online), there is a deficit of 39,434 MW to be met. About 50 % of the population does not have access to electricity (ECN, 2013a, p. 6). Most rural communities are not connected to the grid and majority of these people use traditional biomass (such as firewood), kerosene lanterns and candles to meet their energy needs which has numerous health and environmental consequences. At the current rate of grid expansion projects, these rural communities will most likely remain underserved; and without energy efficiency considerations, the existing energy generation and supply infrastructure will require

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<sup>20</sup> Based on World Bank data, the Nigeria population is growing at an average of 2.6 % annually and is expected to reach about 264 million in 2030; likewise, the economy is growing at an average of 4.1 %. In reference to information from the United States Agency for International Development (USAID), Nigeria became the largest economy in Africa with a 2013 gross domestic product (GDP) of US\$ 510 billion. Information available online at: [https://www.usaid.gov/sites/default/files/documents/1860/Nigeria%20\\_IG\\_2015\\_05\\_03.pdf](https://www.usaid.gov/sites/default/files/documents/1860/Nigeria%20_IG_2015_05_03.pdf)



significant additions in the coming decade through capital intensive grid expansion projects. By using inefficient appliances, end-users spend more on energy bills and consume more energy than is necessary. The anticipated economic growth and increasing population also translate to high CO<sub>2</sub> emissions rates. The Nigeria's NDC report shows that, under a business-as-usual growth scenario, with an estimated economic growth rate of 5 % per year, Nigeria's total CO<sub>2</sub> emissions are expected to grow to around 900 million tonnes per year in 2030 (about 3.4 tonnes per individual) (Nigeria NDC Report, 2017, p. 9). The residential sector in Nigeria is vulnerable to the impacts of climate change. Rising temperatures would most likely result in increased energy demand for air conditioning and refrigeration. And this is irrespective of severe shortages of energy supply. As a signatory to the Paris Agreement, and as one of the twenty-five top GHG emitting countries (Climate scorecard, 2017), Nigeria is under obligation to achieve the pledges as stipulated in the nation's NDC report.

As the government strives to experiment on energy efficiency as a means of restraining growth in energy consumption, research is needed to focus their design to target the main potentials and as such, avoid wasting resources in planning and implementing those policies that may not yield the desired outcome. It will also enhance knowledge on the complexities of establishing such policies and ensure that the outcomes serve as a justification for their introduction. Policy design could be crucial in the public policy development process because it may greatly determine the performance of such policy measures. Reports from both the European Commission (EC) and ECN affirms that creating energy efficiency awareness and developing policies and strategies to support it could be a cost-effective way of complementing government effort in mitigating the increasing trend in energy consumption. It will also enhance access to modern energy supply, reduce transmission network load and associated emissions, enhance industrial competitiveness, create employment and business opportunities, among other co-benefits (ECN, 2013a, p. 2; EC, 2012, p. 1). Also, the outcome of this dissertation will provide preliminary quantitative information on energy efficiency savings potential and end-use patterns, especially in households, and as a result, bridge the current gap on absence of data and baseline information and reiterate the need for better data using a nation-wide survey to provide a comprehensive picture of current residential energy use patterns.

## 1.10 DEFINITION OF TERMS

In respect to this dissertation, the following concepts are further elaborated which are guided by the consultation of various scientific literature and publications from relevant MDAs.

*End-use energy efficiency:* Energy efficiency has been defined in several terms in literature but with a key message of reducing the energy consumption of products and/or processes. The report of the GIZ on the Nigerian energy sector, under the Nigerian Energy Support Program (NESP), defines energy efficiency as using less energy to produce the same service (GIZ, 2015, p. 104). Similarly, the Asian Development Bank (ADB) in their report, “Energy efficiency development and potential energy savings in the Greater Mekong sub-region”, defines energy efficiency as reducing the energy required for a given level of activity or doing more with less (ADB, 2015, p. 2). These definitions represent a more holistic expression of the concept of energy efficiency. On the demand-side, the term energy efficiency refers to energy end-use efficiency. Irrek and Thomas (2008, p. 3) of the Wuppertal Institute for Climate, Environment, Energy (Wuppertal Institut für Klima, Umwelt, Energie) gave a concise definition of end-use energy efficiency; “the proportion of the amount of energy used for the satisfaction of personal needs and energy use of non-personal demand.” The interpretation of this definition is that the physical impact or benefit achieved by an energy application is the major attention regarding the measurement of end-use energy efficiency e.g. cooling of a refrigerator. Based on the contextualized position of this research, the definition of end-use energy efficiency will be narrowed down to “increase in end-use energy efficiency.” In this dissertation, the following definition is adapted to describe an increase in end-use energy efficiency; using less end-use energy to provide the same or improved level of service resulting in energy and emissions savings. Irrek and Thomas (2008, p. 3) remark that increase in end-use energy efficiency can be achieved through technical, organizational, institutional, or structural changes.

It is essential to distinguish between end-use energy efficiency and energy conservation. End-use energy efficiency measures, such as replacing an incandescent light bulb with a compact fluorescent lamp (CFL) help reduce energy input while rendering the same or improved level of output service. On the other hand, energy conservation (mostly, involving behavioral aspects) such as switching off lights and appliances when not in use, help reduce energy consumption. Both end-use energy efficiency and energy conservation help reduce energy use and

greenhouse gas emissions and as well, lower energy costs. However, this dissertation focuses more on end-use energy efficiency but make references to energy conservation where necessary.

*Household:* The National Population Commission of Nigeria (NPC) definition of a household will be adopted in this research. The definition was employed in the report of the 2006 population and housing census of the Federal Republic of Nigeria. The definition refers to a household as, “consisting of a person or a group of persons living together normally under the same roof or within the same building/compound, sharing the same food source and recognize themselves as a social unit” (NPC, 2006, p. 7). The NPC classified households into two major groups:

*Regular households:* This comprises of households that recognize one of its members as the head of the household. This may include a one-member household consisting of a single individual (male or female) or a multi-person household which is made up of two or more individuals. Furthermore, the population and housing census exercise classified regular households by type of housing units.<sup>21</sup>

*Institutional households:* households where members do not have any recognized head.

For statistical and analytical purposes, the definition of regular household fits more within the context of this research. This classification supports both the scientific research positioning of this dissertation and guides its methodological choices for primary data collection especially in the selection of sampling techniques adopted for the research.

*Policy:* Hayes (2014, p. 2) defined policy as a “purposive and consistent course of action produced as a response to a perceived problem of a constituency, formulated by a specific political process, and adopted, implemented and enforced by public agency”. A policy has also been defined as, “A theoretical or technical instrument that is designed to solve particular problems directly or indirectly affecting societies within different periods and geographical spaces” (Estrada, 2011, p. 2). There has been a divergence of conception in the literature on the definition of public policy. However, a more specific definition for energy policy will be discussed in section 2.4 and detailed conceptual consideration for the choice of this definition will be given which takes its departure from the research background.

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<sup>21</sup> Distribution of regular households by type of housing unit: House on a separate stand or yard; Traditional/Hut structure made of traditional material; Flat in block of flats; Semi-detached house; Rooms/Let in house; Informal/Improvised dwelling; others (NPC, 2006, p. 10).

*Appliance:* There are several definitions in the dictionary for the word appliance. However, in consideration of the contextual positioning of this research, the following definition according to the Cambridge English Dictionary will be adopted; “a device, machine, or piece of equipment, especially an electric one that is used in the house...” (Cambridge Dictionary, 2017). It should be mentioned here that the word appliance as used in this dissertation may in some circumstances represent all three devices (lighting, refrigerators and air conditioners) under review.

*Urban area:* “An area where people live in continuously build-up areas in places with a population of 1,000 or more people and a population density of 400 or more people per km<sup>2</sup>”. This definition of an urban area is extracted from Statistics Canada (2005).<sup>22</sup>

### **1.11 THESIS OUTLINE**

This thesis consists of a total of ten chapters.

Chapter 1 presents the thesis foundation. It describes the general overview and context of the dissertation by discussing the background information, research problem, the main aim and specific objectives of the research, research questions that guided the study, hypotheses, the justification of the study and target audience, the scope of the work and various limitations experienced during the course of the research. It also expresses the main motivation for conducting the research and finally, outlined the main contents of the thesis.

Chapter 2 presents the overall literature review of the research and aspects of the conceptual framework. It focuses on key conceptual considerations of the research methodology and of the type of energy efficiency analysis conducted in this research. It also introduces the theoretical constructs of the policy evaluation criteria adopted in this study and the choice of these evaluation criteria.

Chapter 3 discusses the research methodology adopted in this dissertation; this includes a presentation of the research positioning and the methods used for data collection. Quantitative and qualitative methods of data analysis are presented including specific analytical frameworks and key modeling based assumptions. The chapter also presents a diagrammatical representation of the entire research framework.

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<sup>22</sup>Available online at: <http://www.statcan.gc.ca/english/research/21-601-MIE/2002061/appendixa.pdf> (Last accessed on: 1.4.2017)

Chapter 4 enumerates general overview of the study area and Nigeria as a whole. This includes geographical location and characteristics and other related energy and environmental problems. Chapter 5 presents the main findings of the household survey and policy impact assessment conducted in this research. The results of the household survey are presented in the form of descriptive statistics and findings from policy impact assessment are represented with Excel generated graphs and also using tables. The chapter also presents discussions of uncertainties associated with the modeling of the policy impacts.

Chapter 6 focuses on the review of institutional mandates and roles and governance of key MDAs in the appliance energy efficiency sub-sector. It reviews the mandates and roles of the selected MDAs in advancing end-use energy efficiency in Nigeria to identify overlaps in institutional activities.

Chapter 7 is a review of relevant international environmental conventions and protocols related to addressing the environmental impacts associated with the use and disposal of energy-efficient products and to which Nigeria is a signatory. The use and disposal of the covered products in this research are discussed based on the context of the reviewed conventions and in relation to the study area.

Chapter 8 evaluates the National Energy Efficiency Action plan (NEEAP) using the adopted criteria (integrated policy framework) as an evaluation benchmark. The assessment is to identify policy gaps that may inhibit the effectiveness of the policy framework in transforming appliance energy efficiency market in Nigeria.

Chapter 9 highlights key barriers in advancing energy efficiency based on challenges identified during the research survey.

Chapter 10 offers concluding findings. It presents key conclusions in respect to the raised research questions and also, the main contributions of the research to the existing body of knowledge. The chapter also highlights key recommendations and presents a proposed tailor-made policy framework which is guided by global best practices. The chapter ends with suggestions on areas of further research.

## **2. LITERATURE REVIEW**

### **2.1 INTRODUCTION TO CHAPTER TWO**

This chapter presents background information on energy efficiency potential, energy efficiency gaps and barriers that create these gaps. Historical trends and key global energy efficiency policies that are considered by international organizations and regional bodies were also reviewed. These policies have been implemented to close the energy efficiency gaps around the world and it ranges from government regulatory measures, capacity building, creation of enabling environments, technology transfer and increased investments in energy efficiency. The chapter also presents methodologies in selected literature that have been adopted in assessing energy efficiency potentials in several case studies. It concludes by reviewing literatures on energy efficiency policy instruments and the importance of the choice of these instruments in ensuring effective policy outcomes.

### **2.2 GENERAL LITERATURE REVIEW.**

The publication of the Club of Rome “Factor Four” presents a crucial insight on the potential and benefits of using resources more efficiently. The report highlights that halving global resource consumption will increase resource productivity by fourfold and will simultaneously double wealth (Weizsäcker et al., 1998). It contributed to the consolidation of the efficiency revolution and discussed several measures of efficient resource use including the critical role efficient use of energy can play in creating sustainable forms of energy resource. Energy efficiency improvement is now gaining extensive global recognition as an energy resource. It has been reported in literature that advancement in energy efficiency presents great benefits such as competitive industries through reduction in energy content of products which reduces variable costs of the production chain; energy cost savings for households through the use of more efficient appliances; improved energy access (especially to the rural poor) through more efficient generation and distribution; technology innovation and providing job creation (see: Constantine, et al., 1999, p. 4; Asian Development Bank, 2015, p. xii, ECN, 2013a, p. 6). Energy efficiency has also been regarded globally, as a key component of strategic measures to decrease dependency on fossil fuel (oil, gas, coal) and thus, mitigate greenhouse gas emissions and the risk of climate change (see: Asian Development Bank, 2015, p. xii; Letschert, et al.,

2013, p. 72). A recent energy efficiency status report of the International Energy Agency (IEA) shows that energy efficiency can assist in the realization of the United Nations (UN) Sustainable Development Goals (SDGs) especially, “ensure access to affordable, reliable, sustainable and modern energy for all – SDG 7) and other SDGs such as actions to combat climate change (SDG 13) and improving household incomes (SDG 8) (IEA, 2018, p. 30). Consequently, several regions around the world have adopted measures and policies to enhance the advancement of energy efficiency and several other regions are at early stages of design and implementation of energy efficiency programs.<sup>23</sup>

### **2.2.1 ENERGY EFFICIENCY POTENTIAL**

The IEA estimated that realizing the existing global efficiency potential would deliver about 22 % cuts in primary energy demand in 2040 compared with current policy scenarios (IEA, 2018, p. 26).<sup>24</sup>The IEA analysis indicated that the estimated reduction in energy demand would subsequently, reduce energy-related greenhouse gas emissions by 12 % compared to current levels, contributing about 40 % of the abatement required to be in line with objectives of the Paris Agreement (IEA, 2018, p. 17). It is estimated that the potential impact of implementing MEPS targeting technically best commercially available efficiencies for a range of products<sup>25</sup> in the residential and industrial sectors of the most energy-consuming economies in the world (United States, European Union, China, India) can reduce 2,600 terawatt-hours (TWh) (about 20 %) of the projected final energy consumption (Letschert et al., 2013, p. 78). As a result, annual carbon dioxide (CO<sub>2</sub>) emissions would be reduced by 1.5 gigatonnes (Gt) (about 13 %) by 2030 compared to BAU estimates whereas the current implemented standards in these countries (for the covered products) will save 200 million tonnes (Mt) of CO<sub>2</sub> emissions by 2030 compared to BAU emissions (Letschert et al., 2013, p. 80). Based on these estimates, implementing standards targeting commercially best available products in the listed countries, represent a nine-fold

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<sup>23</sup> Countries such as the United States of America, Republic of South Africa, the European Union, have introduced policy measures such as MEPS, energy labels, financial incentives, etc. geared towards improvement in energy efficiency.

<sup>24</sup> This assessment is based on the assumption that policies are implemented to allow the market to realize the potential of all known energy efficiency measures that are economically viable and the sectors included in the analysis are: industry, transport and residential and non-residential buildings; electricity generation industry and supply-side measures (such as renewables and carbon capture storage were not considered in the analysis (IEA, 2018, p. 25).

<sup>25</sup> The range of products covered in the study are for both sectors: lighting, televisions, refrigerator-freezers, freezers, water heaters, room air conditioners, central air conditioners and heat pumps, furnaces, boilers, ceiling fans, standby power, clothes dryers, motors, distribution transformers (Letschert et al., 2013, p. 3).

increase in CO<sub>2</sub> emissions savings. In a similar analysis, Jolland, et al. (2010) estimated that energy efficiency policies could save approximately 20 % of the final energy consumption from 2010 to 2030 in five major sectors (buildings, lighting, appliances, transport and industry) in the Organisation for Economic Co-operation and Development (OECD) countries. The energy savings potential in developing economies could even be higher than that attributed to the OECD countries due to the widespread use of inefficient appliances and other energy technologies.

### **2.2.2 ENERGY EFFICIENCY GAPS AND BARRIERS**

Energy efficiency gap can be defined as the difference between the higher levels of possible energy savings that can be achieved and the energy efficiency levels that are currently being achieved. Energy efficiency gaps occur when there is potential for improved energy savings but lack of measures to address it. These measures usually target several barriers that hinder the advancement of energy efficiency. In reference to IEA (2010, p. 35), these barriers can come in many forms which may include: lack of affordable energy-efficient technologies, lack of access to efficient technology, lack of understanding of energy efficiency investments and poor awareness of the economic benefits of using energy-efficient instruments, policy framework that encourage utilities to only sell energy rather than also invest in cost-effective energy efficiency programs, institutional bias towards supply-side improvements, information asymmetry. The understanding of these barriers can be explained from different perspectives depending on the area of study (engineering, sociology, economics, anthropology and psychology). Golove and Eto (1996, p. 9) expressed the contribution of poor and inadequate regulation as part of barriers creating energy efficiency gaps. Thollander and Dotzauer (2010, p. 7) highlighted the importance of identifying these barriers in order to design appropriate measures to reduce energy efficiency gaps and enhance its advancement. In another related study, Thollander and Ottoson argued that barriers have shown to vary depending on regional or sector-specific conditions and thus, emphasize on the need for regional and sector-specific studies in order to observe these barriers for appropriate policy planning (Thollander and Ottoson 2008, p. 3). Bashmakov and Myshak evaluated the effectiveness of energy efficiency policies launched in the Russian Federation in addressing key barriers to energy efficiency improvements and observed that in the public and housing sector where energy efficiency policies were most actively implemented, significant improvement in energy efficiency was



achieved (Bashmakov and Myshak, 2014, p. 757). Fleitera et al. (2012) evaluated measures to overcome barriers to energy efficiency in Germany through the provision of grants for energy audits in small and medium enterprises (SMEs). The study argues that high investment costs hamper the adoption of energy-efficient measures, even when these measures are considered profitable and concludes that investment subsidies or soft loans may help in accelerating the uptake of energy efficiency measures in SMEs (Fleitera et al., 2012, p. 30).

### **2.2.3 METHODOLOGY FOR ENERGY EFFICIENCY POLICY IMPACT ASSESSMENT**

Various studies have adopted several methodologies to measure energy savings potentials.

Letschert et al., (2013, p. 73) used a modeling framework; the bottom-up energy analysis system (BUENAS) developed by the Lawrence Berkeley National Laboratory (LBNL) in Berkeley, United States, to evaluate the energy and emissions savings impact of implementing MEPS targeting best commercially available technologies for a range of products in the world's most energy consuming economies (see section 2.2.1). Rogan et al. (2014) used a top-down model to project energy demand and supply in Ireland. The model examined the policy impact on energy demand of a selection of current and planned energy efficiency measures which provided insights for the review and design of energy efficiency policies. Kesicki and Yanagisawa (2015) explained the modeling of energy efficiency in the industrial sector using the methodology presented in the IEA's World Energy Outlook and estimated the potential for energy savings in Japan's industrial sector. Mukherjee (2008) used the Data Envelopment Analysis (DEA) to measure energy efficiency in the manufacturing sector in different states of India. A similar methodology was also used by Hu et al. (2012) to study energy efficiency in Taiwan and also, Wang, et al. (2012) applied the same methodology in China. Shui et al. (2015) proposed a mathematical modeling to estimate energy demand and to assess energy efficiency in the auto manufacturing sector. The United for Efficiency (U4E) (a UN Environment initiative) used the Policy Analysis Modeling System (PAMS) to estimate end-use energy savings for refrigerators and air conditioners in the U4E country assessment (U4E, 2016).

There is limited literature on the assessment of end-use energy consumption and savings projections in Nigeria with a particular focus on the residential sector. The ECN used the Model for Analysis of Energy Demand (MAED) to estimate total electricity demand projection to 2030 partitioned into four different scenarios each characterized by an assumed GDP growth rate (a

reference scenario at 7 % GDP growth, high scenario at 10 % GDP growth rate, optimistic scenario I and optimistic scenario II at 11.5 % and 13 % GDP growth rates respectively). From the base year of 2009, the study projected an increase in electricity demand from 4,052 megawatts (MW) to 251,224 MW in 2030 under the optimistic scenario I (ECN, 2014, p. 11). Olayande and Rogo (2008) also performed a similar analysis with a base year from 2005. The study also used MAED to project an increasing trend in total energy demand (including electricity and partitioned similarly as in the case of ECN, 2014). It estimated an increase in electricity demand from 5,746 MW in 2005 to 119,200 MW in 2030 under a reference base scenario characterized by a 7 % GDP growth rate and an increase from 5,746 MW in 2005 to 250,000 MW in 2030 under the optimistic scenario I at 11.5 % GDP growth rate (Olayande and Rogo, 2008, p. 24).

These assessments employed a top-down approach and can provide useful information for plans to improve supply-side capacity. The differences in estimated values in the case for Nigeria, however, call for the need for a proper demand forecast.

This research adopts a bottom-up approach to assess policy impacts of current developed MEPS and MEPS targeting more stringent level, compared to BAU. This means that the study can provide insight on baseline appliance energy use and the potential impact of implementing the current standard regulations and the impact of scaling up current standards to a more stringent level. Such information could create the necessary political will and awareness on the need to adopt measures geared towards the diffusion of efficient appliances. As a result, the resulting trajectories from the energy demand projections in Nigeria, as conducted by the authors reviewed above, cannot be considered as projections based on energy efficiency policy measures. The ECN performed a baseline study that only considered current levels of household end-use electricity usage. The study guided the development of the current MEPS for light bulbs, refrigerators and air conditioners in Nigeria (ECN, 2013a, p. 7).

### **2.3 TYPES OF ENERGY EFFICIENCY POTENTIAL**

There are notably four basic classifications of energy efficiency potential types in the literature (The United States Environmental Protection Agency (EPA), 2007, p. 21; Asian Development Bank, 2015, p. 5; ICF International, 2012, p. 1; Neubauer, 2014, p. 6). Each of this potential type is characterized by different methodology and assumptions to perform the analysis which in

turn depends on what the study aims to estimate. The classifications include: technical, economic, achievable and program potentials.

- Technical potential refers to potential energy savings that can be achieved through immediate implementation of all technically possible efficiency gains irrespective of engineering and economic constraints such as cost-effectiveness and the willingness of end-users to pay for such measures. Technical potential estimate varies depending on efficiency levels or designs adopted in the modeling. Advances in technology usually enhance energy savings. Technical potential gives an insight on the amount of energy use that could be displaced by a particular efficiency level. Methodologies and assumptions for estimating technical and economic potentials are well established when compared to assumptions and methodologies for estimating achievable and program potentials (Neubauer, 2014, p. 7). Several studies have reported results that are based on technical potential analysis (Brown and Wang, 2013; GEP<sup>26</sup>, 2010; GEP, 2011a; ACEEE<sup>27</sup>, 2013; Letschert, et al., 2013). Although these studies adopt quite different levels of engagement of emerging technologies (efficiency designs), their definitions of technical potential generally remain the same.
- Economic potential refers to the subcategory of technical potential that is economically viable to the end-user (from a bottom-up analysis consideration). From a top-down consideration, it can be referred to as potential saving that is cost-effective when compared to a conventional supply-side resource (Neubauer, 2014, p. 6). For the end-user, the savings from energy cost (electricity costs) resulting from the use of a more efficient appliance should offset the extra investment cost needed to install such efficient appliance within the appliance useful life period for it to be considered economically viable. Raising awareness of the economic benefits of using efficient household appliances is necessary to promote their diffusion. Lower electricity tariffs and high investment costs of energy-efficient appliances may negatively affect the economic potential of efficiency measures and also make them less attractive to consumers.
- Achievable potential represents the amount of energy use that an energy efficiency measure or design is expected to displace under a most aggressive program scenario. A

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<sup>26</sup> GEP is Global Energy Partners, LLC, New York.

<sup>27</sup> ACEEE is the American Council for an Energy-Efficient Economy, based in Washington, District of Columbia (D.C.).

typical example of an achievable potential assessment was conducted in ICF international (2012).<sup>28</sup>

- Program potential consists of energy savings resulting from a specified program design and funding level (Asian Development Bank, 2015, p. 5). Program potential is usually considered a subdivision of achievable potential or somehow similar to it.

Based on the contextualized position of this research, the definition of technical potential fits in the type of assessment conducted in this study. Economic and achievable potential types of assessment are beyond the scope of this dissertation and as a result; do not fit within the context of the research.

## **2.4 POLICY DESIGN – THE CHOICE OF INSTRUMENTS TO CLOSE ENERGY EFFICIENCY GAPS**

Removing barriers to energy efficiency using government policies and measures have been well reported in the energy literature. Estrada (2011) defines a policy as, “a theoretical or procedural instrument that is designed to solve a particular problem affecting societies directly or indirectly within different periods of time and geographical spaces” (Estrada, 2011, p. 2). Given the background of this research (that is, the impacts of increased energy efficiency), it becomes imperative to understand a policy within the context of energy policy. Recently, and within the auspices of the UN, energy policy has been positioned in the concept of SEforAll initiative.<sup>29</sup> This initiative is expected to provide a platform to accelerate the transformation of the World’s energy systems, reduce energy poverty and enhance prosperity. The specific aims of the initiative are; the need for all stakeholders to work towards ensuring universal access to modern energy services; double the global rate of improvement in energy efficiency and double the share of renewable energy in the global energy mix, within the UN timeframe of 2030 (SEforAll online portal). National governments now design and implement integrated country actions to address barriers and strategically transform their energy systems by adopting various policy instruments. In consideration of the specific research background (i.e. energy and emission savings potential of improved energy efficiency) energy policy as attributed to the case of

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<sup>28</sup> The ICF study considered factors such as baseline energy use, energy costs, current levels of efficiency, market saturation, program incentive levels, program market barriers and regulatory treatments to identify savings that could be realistically achieved through utility initiated programs (ICF international, 2012, p. 1).

<sup>29</sup>The United Nations (UN) Secretary-General, Ban Ki-Moon, launched the SEforAll initiative in 2011.

energy efficiency is adapted here to mean government action agendas and decisions for the advancement of energy efficiency and its emissions and energy savings impacts. This conceptual position addresses the energy and environment interplay of energy efficiency. The research focuses on energy and emission savings potential of energy efficiency improvements and this conceptual choice guided the overall scope of the research. The main measures that governments use to exercise their power through public policy lie in policy instruments. Policy instruments are tools the administrators use to implement their policy objectives (Kelly, 2012, p. 8). The choice of a particular policy instrument to solve an identified societal problem is guided by empirical findings to maximize its effectiveness and efficiency. Consequently, the research takes its departure from the fact that “public policy, especially policy instruments, is the object of empirical findings and policy evaluation” (Fischer, 1995).

Three notable types of policy instruments that have been widely implemented to advance appliance energy efficiency and to address the significant energy use and emissions associated with appliance usage are; regulatory instruments, information instruments and economic instruments (Kelly, 2012, p. 25; Streimikiene, 2014, p. 289; Bocher, 2012, p. 14). The section following discusses these policy instruments and provides several examples of each instrument.

**Regulatory instruments:** Regulatory instruments define minimum performance levels that must be met before an appliance can be sold in an economy (U4E policy guide series, 2017a, p. 16). Regulatory instruments adopt a command and control principle to change consumers’ behavior. Through legislation, governments enact laws that mandate people to attain certain targets or renounce participation in certain activities. Regulatory instruments usually adopt non-compliance or legal penalties (such as the payment of fines) to ensure people comply with established laws. It is reported that regulatory instruments on its own, fail to provide incentives for the realization of a desired policy outcome and thus, have been criticized for not providing stimulus to motivate efforts extending beyond simply meeting legal obligations (Knopp, 2008, p. 57). Consequently, policy makers rarely employ only this type of measures (Knopp, 2008, p. 53). Regulatory instruments related to appliance energy efficiency are basically MEPS for appliances. The objective of MEPS is to reduce the overall energy consumption of a targeted appliance in its delivery of the desired service (Kelly, 2012, p. 20). Market assessment of the targeted economy

should be conducted before the development of MEPS and the energy savings, environmental performance and economic impacts of the proposed MEPS determined (Kelly, 2012, p. 22).

**Information instruments:** Information instruments provide knowledge to consumers and other actors in an attempt to influence purchase decisions. The rationale surrounding informative instruments is that actors lack some of the knowledge necessary to aid them in making the right decisions. It is expected that the provision of necessary information increases awareness which empowers people to act and behave in a more predictable manner. Common informative instruments associated with appliance energy efficiency are communication campaigns, appliance energy performance labels, pilot programs, educational and advice centers and capacity building programs. These instruments set out to address information deficiency in relation to products' characteristics and thus, enhance purchaser's knowledge.

**Economic instruments:** Economic instruments utilize market-based mechanisms of prices to influence the behavior of actors (Bocher, 2012, p. 14). It provides financial incentives or disincentives that change the economic situations of targeted participants. Economic instruments usually applicable in the field of appliance energy efficiency are tax concessions, subsidies, provision of soft loans, technology public procurement, on-bill financing and rebate programs for targeted participants. Economic instruments basically, modify the price range within which consumers make purchase decisions in order to make the purchase of more efficient products more attractive (Kelly, 2012, p. 23).

There is no particular specific rule governing the choice of policy instruments rather, the decisions are usually based on the nature of the empirically identified societal problems and effective policy interaction impacts of policy instruments. Carter (2001, p. 286) acknowledges that it is difficult to create clear distinctions between policy instruments as they often share common relationships. Kelly (2012) argues that information instruments are not quite effective in influencing consumer's decision to purchase efficient appliances when compared to economic instruments such as subsidies; the latter is more likely to induce the uptake of efficient appliances (Kelly, 2012, p. 25). However, the study pointed out that policy instrument such as MEPS enacted into law and subjected to adequate enforcement and monitoring is most likely to create the desired changes towards the adoption of efficient appliances (Kelly, 2012, p. 26). Most of the reviewed literature did not address energy efficiency policy instruments based

on the interplay of energy and environment issues. However, few studies (Bressers and Huitema, 1999, p. 14; Varone and Aebischer, 2001, p. 619; Murphy et al., 2012, p. 461) mentioned that combination of instruments is required to achieve energy and environmental benefits of energy efficiency policies. Varone and Aebischer further reiterate that efficient policy action must rely on a combination of instruments (policy mix) that considers all stages of the appliance's life cycle to achieve a transformation of the market structure (Varone and Aebischer, 2001, p. 619). In realization of the role energy efficiency policy instruments play in addressing energy and environment issues, the UN Environment also asserts that the combination of policy instruments is essential for an effective transition to energy-efficient market (UN Environment, 2013, p. 5). Consequently, the UNEP en-Lighten Africa Initiative sets out a standard framework "an integrated policy approach" (see section 2.4.1 of this chapter) which comprises of four basic policy instruments: MEPS, supporting or complementary policies (such as labelling, awareness creation and financial mechanisms, etc), monitoring, verification and enforcement mechanisms and environmentally sound management measures (UN Environment, 2013, 5). The inclusion of environmentally sound management measures in the integrated policy framework would assist to address energy efficiency policy instruments based on the interplay of energy and environmental issues of appliance usage.

Many countries have adopted an integrated policy approach for the advancement of energy efficiency. For instance, the 2012 Energy Efficiency Directive of the European Commission (EC) provides binding policy instruments in the European Union (EU) member states aimed at energy efficiency improvement and to assist the EU in reaching its 20 % reduction in primary energy consumption by 2020.<sup>30</sup> The EC Directive (2012) introduced various policy instruments such as MEPS, subsidies and tax exemptions, labeling programs, awareness campaigns, adequate enforcement and proper disposal and recycling of end-of-life products. It is believed that these measures have contributed to the huge success of energy-efficient appliance transition in several EU States (Filippini et al., 2014, p. 3).

As a region where energy efficiency measures are not yet well established, the Economic Community of West African States (ECOWAS) through the ECOWAS Centre for Renewable

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<sup>30</sup>Directive 2012/27/EU of The European Parliament and of The Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. Official Journal of the European Union. Online at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399375464230&uri=CELEX:32012L0027> (Last accessed on: 30.11.2017).

Energy and Energy Efficiency (ECREEE) developed the ECOWAS Energy efficiency policy (EEEP) which advocates for the adoption of an integrated policy framework in member states for the advancement of energy efficiency in the region (FMP, 2016, p. 53). Nigeria has commenced the process of integrating energy efficiency in its energy policies. The development and approval of key policy documents such as the National Renewable Energy and Energy Efficiency Policy (NREEEP), The National Energy Efficiency Action Plans (NEEAP) which are both developed by the Federal Ministry of Power (FMP) in collaboration with the Inter Ministerial Committee on Renewable Energy and Energy efficiency (ICREEE), underscores government's effort towards championing energy efficiency in the country. The NREEEP (2015) can be described as the government's statement of intent to embark on energy efficiency actions while the NEEAP (2016) enumerates government's actions to drive energy efficiency in the country. The NEEAP adopts a combination of policy instruments (in an integrated policy model) to achieve an effective energy-efficient market transformation in Nigeria.

The following section examines in details the four basic components of the integrated policy approach.

#### **2.4.1 THE INTEGRATED POLICY APPROACH**

The integrated policy approach was initiated by the UN Environment to assist countries (especially emerging economies who do not have regulations or who are in the process of developing regulations to mitigate energy and climate impacts of lighting and electrical appliances) undergo effective transition to energy-efficient technologies. Since energy efficiency is multi-sectoral, UN Environment affirms that following an integrated policy approach in energy efficiency activities ensures the involvement of all key stakeholders during the planning and implementation stages which may help to improve the effectiveness of the entire policy outcome (UN Environment, 2013, p. 5). The UN Environment report also advocates for a tailor-made approach when adopting integrated policies in order to suit respective national contexts and existing regulatory frameworks and as well, underscores the need for regional harmonization and sharing of experiences and resources with neighboring economies to reduce the costs of implementing these strategies. The integrated policy framework classified energy efficiency policy instruments into four major instruments and the policies target appliances powered by grid-connected electricity:



**Minimum energy performance standards (MEPS):** These are regulatory measures that state the minimum efficiency levels of products allowed to be sold or marketed in a particular country or region. It communicates minimum performance requirements for all products. It is recommended that adopted standards should conform to appropriate international best practices as established by relevant international bodies such as the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). The setting of MEPS is based on the baseline efficiency level of the targeted market. However, MEPS should align with trends in technology innovations in order not to create efficiency gaps in the relevant economy. When properly implemented, MEPS ensures the elimination of inefficient appliances from the market and thus, preempt consumer preference, by limiting consumer choice only to products that meet established minimum performance levels. The general acceptance or effectiveness of the MEPS program is highly dependent on the compatibility of other complementary policies in the entire integrated policy framework (UN Environment, 2013, p. 6). To explain this, the establishment of standards for light bulbs on its own, may not enhance general widespread diffusion of efficient light bulbs without other complementary policies such as fiscal or economic-based policy instruments that address the challenges of high initial costs of efficient light bulbs when compared to the existing inefficient types of light bulbs. Likewise, appropriate environmental sound management measures should be taken into consideration, because the expected widespread acceptance of efficient lamps (in this case, CFLs which contains mercury) may result in the accumulation of mercury wastes from burned-out light bulbs. However, the establishment and implementation of standards are imperative to the development of the market for efficient technologies because it serves as a push factor to manufacturers and/or importers to produce and/or import products that meet or exceed established thresholds. As stated earlier, standards or regulatory instruments do not provide incentives beyond that level. Complementarily, the implementation of different types of policy instruments such as subsidies, awareness campaigns, tax breaks, etc, serves as a pull factor by providing further incentives necessary for a successful transition to an energy-efficient economy. A report of the United for Efficiency (U4E) however, highlights the need to conduct technical, economic, environmental and market analysis to inform the standards-setting process in the targeted economy (U4E policy guide series, 2017a, p. 15).

**Supporting policies and mechanisms:** To ensure the effectiveness and successful implementation of MEPS, several complementary or supporting policies are imperative. Supporting policies comprises a combination of economic, market, communications and financial incentive measures, which have been listed in the general literature review section, carefully designed by national governments to overcome perceived barriers to energy efficiency diffusion. The UN Environment report suggests the combination of the following complementary measures to support a successful implementation of MEPS (UN Environment, 2013, p. 6).

- **Regulatory and control mechanisms:** These comprise of regulations and laws that prohibit the sale of certain products in the market such as the ban of inefficient or the ban on the importation of used and old appliances like old refrigerators. The mechanism, if properly regulated and enforced, creates room for the availability of only efficient appliances in the market.
- **Economic and market-based instruments:** These include instruments aimed at correcting market failures such as cost reflective tariff structure.
- **Fiscal instruments:** These are mechanisms that impact prices such as tax reductions or financial incentives, on-bill financing to overcome high initial investment costs of energy-efficient products.
- **Information dissemination:** This supports established standards by ensuring that information conveying details about the efficient products is clearly and consistently communicated. Recommended information dissemination means Include comparative and/or endorsement labels to help consumers make informed decisions during purchase, awareness creation to induce behavioral changes among decision makers and end-users to adopt energy-efficient technologies. Such information may include communicating energy costs savings arising from the use of efficient products to consumers and informing decision makers of the energy costs and emission savings potential of energy efficiency. The adopted means of communication to end-users will most likely determine the success of the awareness program.

**Monitoring, Verification and Enforcement (MVE) systems:** The compliance to the established MEPS depends largely on adequately functioning framework of monitoring, verification and

enforcement activities. Monitoring is a process to determine product efficiency, verification is a testing process through which declarations of conformity by product suppliers are confirmed or verified and enforcement is collective action(s) employed by program administrators or other responsible government agencies against suppliers of non-compliant products. It is recommended that appliance verification test methods should conform to relevant IEC and ISO specified test methods (for lighting, refrigerators and air conditioners). For instance, the IEC 62552: 2015<sup>31</sup> test procedure should be adopted as the test method for verifying refrigerator performance (U4E policy guide series, 2017b, p. 26) and it is recommended that the energy efficiency ratio (EER)<sup>32</sup> can be used as a metric for assessing air conditioner efficiency, especially in countries where MEPS are being developed for the first time (U4E Policy guide series, 2017c, p. 34). Also, specific ISO standards for air conditioner testing and performance ratings should be adopted (such as the ISO 5151<sup>33</sup>) (U4E Policy guide series, 2017c, p. 33). Aligning verification test method to recommended international best practices will also minimize trade barriers and compliance costs for manufacturers (U4E policy guide series, 2017c, p. 40). One of the dangers of inadequate MVE measures is the proliferation of sub-standard products. The proliferation of poor quality products will affect expected energy, emission and energy costs savings of the established MEPS. It will also reduce end-users' satisfaction which may consequently, lead to end-users refraining from continuously buying energy-efficient products in the future. Policy makers are highly encouraged to develop and also adopt recommended MVE measures into energy efficiency program activities. Figure 2.1 is a fundamental MVE process; it highlights key aspects of the MVE process to guide the design and setting up of MVE framework. It is reported that the sharing of information and skills between countries and regions greatly enhances MVE capacity (UN Environment, 2013, p. 7).

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<sup>31</sup> The IEC 62552: 2015 is established by the International Electrotechnical Commission and it specifies the essential parameters and/or characteristics of household refrigerators and specifies test methods for verifying the characteristics (IEC webstore, 2018).

<sup>32</sup> EER is the ratio of the measured cooling capacity (in kW) in relation to the power input for cooling (kW) of an air conditioning unit measured at standard rating conditions (SON, 2013a, p. 5)

<sup>33</sup> The ISO 5151 specifies standard conditions, test methods for determining the capacity and performance rating for air-cooled air conditioners and heat pumps (ISO, 2017).

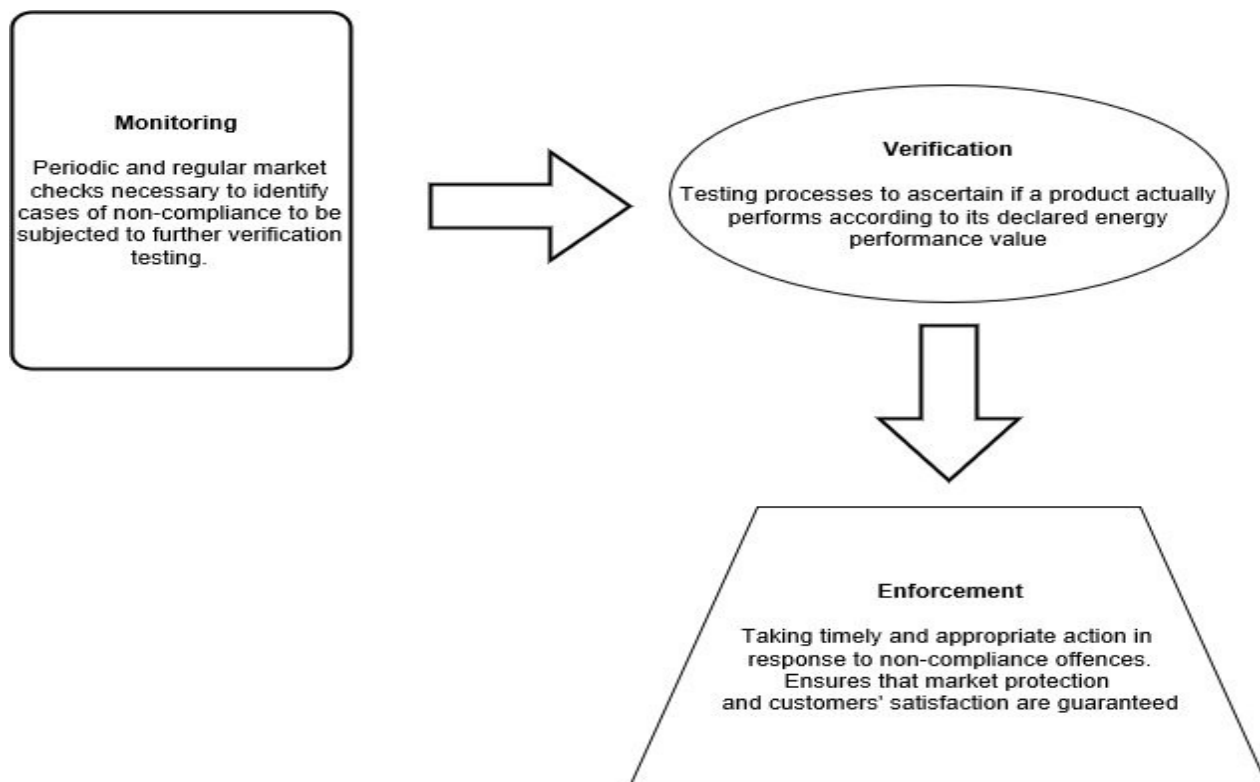


Figure 2.1 Fundamental aspects of the MVE process (Source: Adapted from U4E policy guide series, 2017c, p. 65).

**Environmentally sound management (EnSM) mechanisms:** EnSM measures are highly recommended as an integrated part of a national energy efficiency program to ensure products do not cause undue harm to people and the environment during the process of manufacturing, operation or disposal and recycling. In this regard, EnSM mechanisms advocate specifying maximum levels of hazardous substances (such as mercury in compact fluorescent lamps or hydrofluorocarbons in refrigerants). For instance, it is recommended that refrigerants used in refrigerators have zero ozone depleting potential (ODP) and a global warming potential (GWP) of 20 or less (U4E policy guide series, 2017b, p. 15).<sup>34</sup> These standards should be in line with global best practices such as the Montreal Protocol<sup>35</sup> and the Minamata Convention on mercury<sup>36</sup> (see chapter 7) and safety requirements such as ISO 5149.<sup>37</sup> The EnSM approach also

<sup>34</sup> Refrigerators that use refrigerants with zero ODP and GWP of 20 or less are considered climate friendly refrigerators (U4E policy guide series, 2017b, p. 15).

<sup>35</sup> The Montreal Protocol on Substances that Deplete the Ozone Layer, adopted on 16 September 1987 and entered into force on 1 January 1989, regulates the phasing out of the production and consumption of substances that can significantly deplete the ozone layer (UN Treaty Series, 1989)

<sup>36</sup> The Minamata Convention on Mercury, which was adopted on 10 October 2013 and entered into force on 16 August 2017, aims to protect human health and the environment from anthropogenic emissions of mercury and mercury compounds (United Nations, 2013).

advocates that the establishment of structures for adequate collection channels and processing facilities for steel, copper, aluminum, plastics and the refrigerant at the end-of-life of refrigerators and air conditioners should be a high national priority (U4E policy guide series, 2017b, p. 68; U4E policy guide series, 2017c, p. 77). This will enhance sustainability in the efforts to implement a comprehensive energy efficiency policy. It also recommended that collection and treatment facilities for burned-out CFLs should be established in designated collection centers to avoid careless disposal and environmental impact from end-of-life CFL lamps.

Figure 2.2 expresses how the integrated policy approach can achieve the transformation of the appliance market. In summary, for a successful energy-efficient market transformation, policy instrument(s) in each of the components of the integrated policy framework should be designed and implemented.

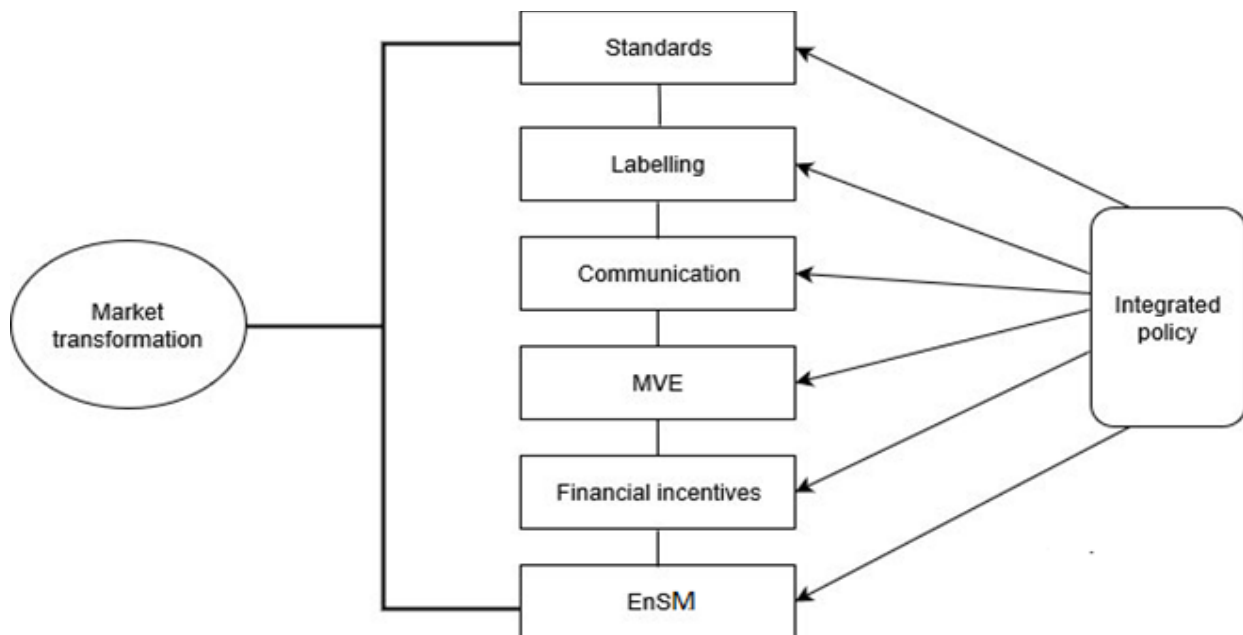


Figure 2.2 Institutional transformation of appliance market through the integrated policy approach (Source: Author).

As highlighted in the NEEAP, The ECOWAS Commission has adopted the above described four basic policy combinations in its ECOWAS Energy Efficiency Policy (EEEP) to guide member states

<sup>37</sup> ISO 5149 establishes safety and environmental requirements for refrigerating systems (ISO 2014).

in championing energy efficiency in their respective countries (FMP, 2016, p. 53). For this research, the integrated policy approach will be employed as an evaluation benchmark in assessing the approved Nigerian National Energy Efficiency Action Plan (NEEAP), which is the only policy document that describes the policy measures and instruments (planned and existing) to advance energy efficiency in the country. This assessment will adopt a critical comparative analysis with the established international and regional best standards and structures to identify gaps. The choice for this approach is consolidated based on the conceptual considerations as presented in the next section and also, based on the fact that it can be adapted to individual country situation or contexts. In addition, the integrated policy approach takes into consideration, the cross-sectional nature of energy efficiency measures and covers the interplay of energy and emission perspective of energy efficiency. The components address market-based, regulatory, informative and environmental policy instruments of energy efficiency and highlights essential parameters or policy instruments in each of these components which enhances the convenience of its application in identifying very critical gaps in established and/or existing energy efficiency policies. The four components of the integrated policy complement each other and explain the dependence of policy instruments in each category in the advancement of energy efficiency. Efforts have been made in this research to adapt the integrated policy approach to accommodate identified specific aspects considered significant in advancing energy efficiency in Nigeria. These aspects are based on empirical findings in the case study area.

#### **2.4.2 POLICY ASSESSMENT CRITERIA – A CONCEPTUAL CONSIDERATION**

Assessment is understood in this research as, “the systematic application of social research procedures for evaluating the design and implementation of policy instruments” (Fischer, 1995; Rossi et al., 2004, p. 4). In reference to Alkin and Christie (2004, p. 12), assessment has two main foundations: accountability and social enquiry. The accountability foundation aims to design and improve policies for the society and the social enquiry foundation of assessment deals with proven and systematic set of methods for determining accountability (Alkin and Christie, 2004, p. 12). Numerous criteria for the assessment of policy instruments abound in literature on public policy and evaluation theory. However, majority of these assessments address economic efficiency and cost-effectiveness of policy measures (see Rossi et al., 2004,

Hilden et al., 2002; Weiss, 1998). Cost-effectiveness evaluates the effectiveness of policy instruments based on their economic efficiency (lowest possible cost options). Considering the scope and focus of this research and building upon the conceptualized definition of energy policy presented in the previous section, “government action agendas and decisions for the advancement of energy efficiency and its emission and energy savings impacts”, it is not intended to conduct a cost-effectiveness assessment of end-use policy measures, such as MEPS. Fischer (1995) established that policy assessment can also evaluate the expected impacts (ex-ante assessment) or the actual results (ex-post assessment) of policy measures. Fischer (1995: pp. 241-242) provides a suitable classification of policy assessment in relation to the empirical and conceptual considerations of the study. First, is the empirical evaluation or assessment which refers to, “the form of assessment that tries to determine the extent to which a specific program or policy empirically meets or does not meet a particular standard or norm”. In this case, the criteria for assessment are the established standards that are the framework upon which a policy choice is conceptualized. The second classification of policy assessment according to Fischer (1995) is the normative assessment which refers to, “assessment that focuses on the standards or norm adopted as criteria in an empirical policy program”. Empirical assessment allows for the identification of policy gaps and thus, it presents policy alternatives that are more likely to achieve established objectives.

In this research, the concept of empirical assessment backs the evaluation criteria adopted for the assessment of the policy measures as detailed in the NEEAP.

## **2.5 THEORETICAL FRAMEWORK**

As in any empirical study, this dissertation faced the daunting task of making theoretical choices. This research is motivated due partly, to the existence of energy efficiency policy gaps in Nigeria. However, for a research finding to inform policy making, it has to go through a political process. This political process determines what is feasible to be implemented and it depends on the political will and capacity of decision makers to embark on policy change. Several benefits and co-benefits of improving energy efficiency have been documented in the literature and there is a record of best practices in energy efficiency reported from various global ex-post experiences that can be adapted to suit a particular local context depending on identified baseline information and barriers. There has been a slow uptake or implementation

of energy efficiency policies in Nigeria. Theoretical choices for the research were made to understand the reason for the slow uptake of energy efficiency measures and the critical aspects surrounding the implementation of energy efficiency policies to achieve effective policy outcome. Theories of policy change (path dependency and policy diffusion) were used to study this phenomenon.

### **2.5.1. PATH DEPENDENCE THEORY**

This theory argues that it is usually difficult to change policies because institutions tend to stick to the existing status quo, and actors protect the existing model (Greener, 2002, p. 614). Levi (1997, p. 28) argues that once a country has taken a particular direction, the costs of turning around is usually very high. Public policies and government institutions are usually designed to be consistent and difficult to change to encourage the continuity of policies (Pierson, 2000, p. 262).

Applying path dependence to energy policy, Fouquet (2016, p. 1) indicates that, “energy systems are subject to path dependence due to technological, infrastructural and behavioral lock-ins”. He further expresses that, even with the potentials of providing cheap and sustainable energy to enhance economic growth and reduce energy poverty, governments often concentrate investments on supply-side, capital intensive, grid engineering projects and fossil fuel subsidy policies. Fouquet (2016, p. 1) argues that even though governments may achieve their objectives through grid expansion projects, they may risk engaging their economies into expensive and energy intensive pathways and lose the opportunity of other cost-effective alternative energy resources.

Unruh (2002, p. 317) and Fouquet (2016, p. 2) underscores the importance of having a clearer understanding of path dependence in energy systems as follows: firstly, the current effort to tackle climate change would require unlocking industrialized nations from fossil-based energy systems by widespread adoption of renewable energy technologies and enhancing energy efficiency improvements; secondly, many developing economies are gradually becoming industrialized and industrialization is a time of heavy investments which creates lock-ins and invariably, path dependence. The ongoing industrialization in developing economies also presents an excellent opportunity to key into sustainable development pathways. According to



Meng (2019, p. 4), path dependence is responsible for the heavy reliance of the United States of America (USA) electricity sector on coal-fired power stations.

The protection of political interests and lobbying by certain stakeholders to protect their interests (such as maintaining fossil-fuel based power generation or subsidies) often locks-in an economy towards an energy-intensive developmental pathway, which leads to path dependence (Fouquet, 2016, p. 5).

The Nigeria's energy policy has mainly focused on improving supply-side capacity. This could be seen from the distribution of the energy supply mix.<sup>38</sup> According to the NREEEP, the over dependence in subsidized oil and gas as primary energy sources has slowed down renewable energy and energy efficiency development in Nigeria (FMP, 2015, p. 6).

Fouquet (2016, pp. 11-12) stresses that it is not very clear how often opportunities for change occur and that depending on the degree of lock-ins towards energy-intensive developmental pathways, the opportunities for change could be less often. Efforts to ensure compliance to Nigeria's NDC presents an opportunity for Nigeria to avoid locking the economy into the antiquated fossil and/or energy-intensive system for a long time that may jeopardize economic prosperity in the long run. Policy diffusion, a process in which policy innovations spread from one government to another, may also create changes (Shipan and Volden, 2008, p. 840).

The methodology adopted in this research is able to demonstrate the possible energy and emission savings potential of improved appliance efficiency. This calls for the need for a nationwide study which may create the necessary awareness and enhance political will among policy makers on the need to mainstream energy efficiency in Nigeria's energy policy.

The major strength of this theory is that it depicts why policy continuity is more likely than policy change. Policies become institutionalized once a country has set on a particular policy path which makes a policy change difficult requiring great efforts and costs by actors who desire change.

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<sup>38</sup>According to a GIZ report, Nigeria's main energy carriers (based on 2012 data): biofuels and waste 80.9 %; natural gas 9.4 %; petroleum products 5.7 %; crude oil 3.61 %; hydropower 0.4 %; coal and peat 0,02 % (GIZ, 2015, p. 26).

### **3. METHODOLOGY**

#### **3.1 INTRODUCTION TO CHAPTER THREE**

The assessment of energy efficiency potential involves establishing a baseline scenario against which future energy savings can be estimated. To ensure a more realistic potential estimate, energy use in the BAU scenario and estimates of potential energy savings, take into cognizance, several assumptions and contributing factors or variables. A realistic potential estimate is essential in understanding the policy impacts of the established MEPS regulation.

Furthermore, the institutional framework conditions must be capable of implementing and enforcing these policy measures at the national and local levels.

This chapter presents the methodology employed during the research process. Generally, the study was conceptualized as policy-oriented research which tries to identify baseline household electricity use and appliance ownership patterns that may guide the planning, design and implementation of energy efficiency policies in order to yield the desired changes towards efficiency and achieve national energy savings and climate targets. The major aim of policy-oriented research is to solve the problem of a society through improved public policies (Fischer, 1995). This methodology is a logical presentation of how the research objectives and questions were addressed to arrive at the research findings and recommendations. The chapter takes its departure by elucidating the research positioning in reference to scientific research paradigms. It highlights the methodological choices and strategies used in data collection, which are from primary as well as secondary sources. Considering the research positioning, primary data were collected both by quantitative and qualitative sources. An in-depth review of both technical and non-technical literature also comprises a major part of the data collection procedure. The chapter also elucidates information on the methods of data analysis and the relevant tools adopted.

The following sections provide further highlights of the various components of the research methodology.

#### **3.2 SCIENTIFIC RESEARCH POSITIONING**

Research paradigms distinguish the various scientific positioning of any research activity. A paradigm is, “a set of framework containing the basic assumptions, ways of thinking and

methodology that are commonly accepted by members of a scientific community” (Dictionary.com). There are four major paradigms in qualitative research that have been classified in the literature: positivism, post-positivism, critical theory and constructivism (Guba and Lincoln, 1994, p. 105). Scientific research paradigms can be explained based on the following assumptions: ontology (philosophy of reality, how things really are and how things really work), epistemology (different forms of knowledge of that reality, distinction between believe and opinion), methodological positions (sets of methods used in a particular area of study to know the reality) (Guba and Lincoln, 1994, p. 108). From the ontological perspective, it is assumed that a “reality” exists which is independent of the researcher’s perceived reality. This means that a real world exists but there is a limited knowledge to know how things really function. Also, there is a social world which is consistently built or interpreted from the perspective of our individual values, experiences and knowledge. The epistemology assumption argues that to discover how things really function, the researcher should adopt an “objective detachment” to inquiry. The methodological assumption highlights the need for adopting an appropriate methodology to ensure objectivity in the study of “reality”. The research is not inclined to the positivist position which is characterized by different researchers producing the same result outcomes at different times, which implies the existence of only one certainty. In reference to the post-positivist, theories are considered revisable and observations fallible. The post-positivist is critical of our ability to know reality with certainty. It argues that “one can only influence and come within reach of reality” (Popper, 1963). This follows that there is a limited understanding of reality and generalizations are reached with a certain level of uncertainty. This reveals the complexity of the world and further buttresses the fact that there are no simple explanations for things. The methodological implication is that, in order to explain situations, research methodologies should be able to capture as much of the complexities, even though capturing it all is equally impossible.

The ontological position is consistent with energy efficiency potential studies as well as, other policy-oriented research and thus, guides their methodological approach. Potential studies provide “knowledge for action” which highlights their exploratory nature. In this instance, knowledge should be empirically based and requires both qualitative and quantitative approach to inquiry. This is to ensure objectivity and rule out the possibility of bringing in researcher’s

social preferences to the study. However, this does not rule out the theoretical aspect of the research which provided the conceptual basis of the study. The epistemological aspect necessitates the need for the design of appropriate methodological frameworks and data collection processes that involves getting inside the circumstances and understanding the societal problems from the various stakeholders' point of views and values (Fischer, 1995).

From the methodological point of view and in reference to the above ontological and epistemological perspectives, the research adopts the use of multiple research methods (quantitative and qualitative) to ensure in-depth analysis and to approximate objectivity and reduce uncertainty. Consequently, the research employs various data sources, methodological analysis and theoretical considerations to address the research objectives.

### **3.2.1 EMPIRICAL RESEARCH APPROACH**

As elaborated in the previous section, the research positioning of this study entails the adoption of both qualitative and quantitative approaches to meaningfully address the formulated research problems and the related research questions and objectives. The qualitative approach is used to analyze the electricity consumption patterns and savings potential in the case study area, to present the background information of policy, institutions and their functions and the setup of the electric power sector in Nigeria. The quantitative approach deals with presenting the required numerical data for measuring the extent, degree and rate of occurrence for comparison and distinguishing set of descriptions. This is presented in this dissertation in the form of tables, charts and figures. The quantitative and qualitative approaches are addressed using “top-down” and “bottom-up” methodologies.

These methodological approaches are necessary to study the advancement of energy efficiency in Nigeria from the perspective of the two key players namely, the relevant government institutions and the electricity end users.

The top-down method delineates how the institution should function in order to create the enabling environment for the promotion of energy efficiency; it adopts comparative analysis, using the integrated policy approach as an evaluation benchmark, to assess the appropriateness of the established national energy efficiency policies as stipulated in the National Energy Efficiency Action Plan (the only energy efficiency policy document) in advancing energy efficiency in Nigeria. It also employs content analysis to identify overlaps and conflicts in

institutional mandates. Data for the top-down analysis were collected via semi-structured interviews, questionnaires and through the extensive review of the NEEAP. The selection of key MDAs was conducted using a snowball sampling method. The bottom-up method assesses appliance ownership rates and patterns by individual electricity user and the impact of the established MEPS standards on reducing electricity demand in residential buildings and bridging the existing electricity supply-demand gap. The bottom-up method also evaluates the possible impacts of scaling-up the current MEPS standards to more stringent levels. The findings could guide the drafting of national policies, setting of energy efficiency targets and planning of support measures for the effective uptake of the MEPS program in Nigeria. One advantage of adopting the “top-down and bottom-up” methods is that both complements each other and reduces the risk of ignoring issues that may be vital to one set of the actors (policy makers and consumers). Figure 3.1 illustrates the top-down and bottom-up methods as adopted in this research to study and offer solutions for the promotion of end-use energy efficiency in Nigeria.

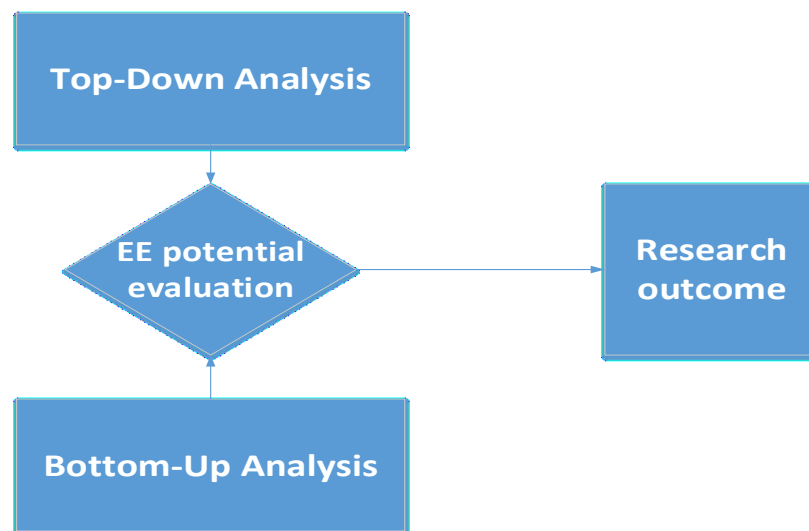


Figure 3.1: Top-down and Bottom-up method (Source: Produced by author)

The data collection and analysis process for the top-down method is explained in details in section 3.3.1 of this dissertation. The bottom-up process involved the collection of data from both primary and secondary sources. Data from both primary and secondary sources provided input parameters for the modeling. Assumptions are emblematic to potential evaluations (Neubauer, 2014, p. 9). These assumptions are typically inherent to forecasting events in the

future. The assumptions are explicitly elaborated and explained (see section 3.3.2). The need for transparency about assumptions is essential because it offers an insight into the evaluation of the research findings and provides a platform for comparisons with other studies (Neubauer, 2014, p. 10). The bottom-up approach involved the following major steps:

**Baseline characterization:** The review of the baseline energy use patterns and appliance ownership in the case study area. This is necessary to determine baseline efficiency and features of the targeted market. It was carried out through an extensive literature review and household survey. The metering study conducted by the Energy Commission of Nigeria (ECN) in 2013 provided information on annual baseline end-use (for the covered products) and household energy consumption for Enugu but the information on baseline end-use consumption does not provide corresponding information on usage and the respective end-use features and characteristics. Therefore, the current baseline end-use energy data is not reasonably precise. However, the metering report guided the choice of the appliances reviewed in this study and presented reasonable information on average household electricity consumption in the case study area which provided a background to understand the capacity of “energy efficiency improvement” as an energy resource. Information on appliance features and characteristics were gathered through household survey and publications from international organizations such as the UN Environment and the International Energy Agency (IEA). Due to the lack of baseline market data, baseline stock data was obtained from the UN Environment and then projected for the entire modeling period. Baseline characterization also expresses the saturation of energy-efficient products within a defined geographical area in a particular base year (ICF International, 2012, p. 7). The household survey also provided accounts of the percentage of customers that have already adopted a certain level of efficiency and this is incorporated into technical potential analysis to reflect the applicability of an energy efficiency measure. Base data period for this research is 2010 to 2015. The selection of the base year is made on the basis of availability of data that are representative of the economic and energy situation of the case study area.

**Level of energy efficiency potential:** The level of energy efficiency potential evaluation is a function of the available baseline data as well as resources available for the research (Neubauer,

2014, p. 6). It also informs the type of data to be collected. For this research, a technical potential evaluation<sup>39</sup> was conducted.

**Data collection:** Includes customer appliance ownership and use patterns, gathering information on relevant household characteristics<sup>40</sup> through survey. Appliance ownership pattern provided information on the appliance saturation levels and appliance characteristics and features. The choice of household data was guided by the relevant information required as input data for the model. Other collected data also served as several input data in the modeling.

**Modeling:** The Lawrence Berkeley National Laboratory (LBNL) – Policy Analysis Modeling System (PAMS) was adopted to forecast the impacts of implementing policies that improve the energy efficiency of new household appliances. The PAMS model is a bottom-up approach spreadsheet that assesses potential energy savings by defining the unit energy consumption (UEC) of the product for different scenarios. The tool allows for analysis with respect to different policy parameters and assumptions (such as information on appliance saturation and stock forecast). PAMS assumes that prior to the introduction of policies such as the appliance standards, products already installed and in use operate at a well-defined baseline efficiency level and after these policies are introduced, it could be interpreted that all products in the market exceed the minimum efficiency level established by the policy. In reference to the input data of a particular appliance type, it uses technical specifications of efficiency design levels for the particular product type or appliance in estimating savings potential. It is designed to operate for variety of countries with the possibility of applying reliable case-specific data inputs. The PAMS was used specifically for projecting impacts from implementing policies that improve the energy efficiency of new household refrigerators and air conditioners. For light bulbs, an individual stock-based model was developed to derive energy consumption and total final energy and emission savings of using a more efficient light bulb (see section 5.1).

**Reference case and alternative policy scenarios:** To study savings potential in the households, three different projection scenarios have been developed; reference case (or business-as-usual) scenario and alternative policy scenarios. The latter is based on the developed appliance

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<sup>39</sup> Technical potential is the “theoretical maximum amount of energy use that could be displaced by improved efficiency, disregarding all non-engineering constraints such as cost-effectiveness and the willingness of end-users to adopt the energy efficiency measures” (Neubauer, 2014, p. 6).

<sup>40</sup> Household characteristics include: employment status, income level, household size, observed number of appliances and their power ratings, hours of usage.

standards and also a higher or more stringent policy standard. The policy tool considered in both cases was varied efficiency levels.

**Study benchmarking:** This involves the comparison of estimates from this research to those from studies of similarly treated contexts.

**Study Outputs:** Finally, the dissertation provides tailor-made actionable factors and policy recommendations that will be based on best-practice recommendations.

### **3.3 METHODS OF DATA COLLECTION**

As stated in section 3.1, the ontological and epistemological position of the research calls for data to be collected from different sources in order to enhance objectivity and reduce the impact of assumptions and uncertainties on the final research findings. The data collection method included the use of secondary data instruments (literature reviews) and primary data instruments (semi-structured interviews, questionnaires, conferences, training sessions and personal observations).

#### **3.3.1 PRIMARY DATA**

Quantitative and qualitative research instruments were employed in this research for primary data collection. Primary quantitative data for bottom-up analysis were gathered through the use of questionnaires and personal observations. Primary qualitative data addresses the top-down method and were acquired through scheduled semi-structured interviews and questionnaires. An in-depth data analysis was carried out on the acquired sets of data.

**Primary quantitative data:** This addresses the bottom-up analysis and involves collecting data through questionnaires, on the current technology ownership rate and use patterns as well as the opportunities and barriers (at the end-use level) to the deployment of energy-efficient technologies in households. To get an overview of the questionnaire design, extensive background research was conducted. Also, the researcher was privileged to participate in a training program on energy efficiency in appliances, lighting and equipment that was administered by the International Energy Agency (IEA) in Paris in June 2015. This training also provided relevant exposure to basic details to be captured in an energy efficiency potential study. Consequently, a questionnaire was structured and drafted. The appropriateness of the draft questionnaire was discussed with the supervising professor of this research and also, during the Ph.D. research seminar at the Brandenburg University of Technology, Cottbus-



Senftenberg, Germany. The recommendations were incorporated into the draft to produce the final version (see Appendix 1).

To determine the sample size of the households to be surveyed, four important parameters that are crucial in determining a representative sample population were taken into consideration:

- **Margin of error:** this is the amount or level of error that one can tolerate. It asserts a probability that the result from a sample is close to the number one could get if the whole population had been sampled. For the purpose of this research, the margin of error that can be tolerated was placed at 5%.
- **Confidence level:** this refers to the amount of uncertainty one can tolerate. The basic idea is that when a population is sampled repeatedly, the confidence level represents the percentage of intervals that would include the population parameters. A 95 % confidence level was used for the determination of the sample size for this research.
- **Population size:** this represents the real or total available population in the case study area from which to choose the sample size. Figures from the official report of the Nigeria National Population Commission (NPC) on the 2006 national population census exercise<sup>41</sup> shows that there are a total of 169,422 regular households by type of housing units in the case study area (NPC, 2006, p. 10).
- **Response distribution:** this factor expresses how skewed a population is in terms of the distribution of the population attributes. This addresses the issue of heterogeneity and homogeneity of the population attributes. A large sample size is required to obtain a given level of precision for a more heterogeneous population and the reverse is the case for a more homogenous population. It should be stated that a proportion of 50 % gives the longest size and addresses a greater level of heterogeneity than either 20 % or 70 %. The distribution of the regular households by type of housing units cuts across six identified types of housing units (NPC, 2006, p. 10). This expresses the heterogeneous nature<sup>42</sup> of the sampled population. Consequently, 50 % response distribution was used for this research.

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<sup>41</sup> The 2006 national population census exercise is the last official census exercise in Nigeria.

<sup>42</sup> Heterogeneous population contains other sub-classifications of the population. It is characterized by diversity.

The above parameters served as input variables in the calculation of the sample size for this research. The internet-based online sample size calculator, “Raosoft”<sup>43</sup> was used to determine a sample size of 384. A total of 390 questionnaires was produced and distributed. The survey was mainly carried out by a face-to-face discussion which encouraged a higher response rate and better quality responses and provided opportunities for personal observations. Even though the questionnaire made use of very simple, non-technical languages, a face-to-face survey also enabled further explanations, where required, for certain questions not clearly understood by respondents.

The questionnaire consists of four sections. Each of the section addresses very specific aspects of the study. Section A provides insight on household characteristics and appliance ownership patterns. Information from this section provided part of the input data to address objective 1 of the research. Section B provides information on household end-use energy baseline data. Information from this section informed part of the input data to address objective 2 of the research. Section C of the questionnaire assesses household energy efficiency awareness levels and factors that influence their choice of appliances. It addressed mainly research objective 5. Section D allows the respondents to raise any other energy-related issues that were not covered. The questions, in this case, were designed to serve as prompts for further discussion. The questions were mainly “close-ended” except for section D which was designed as “open-ended” questions. Some of the questions were inevitably, in the yes/no format; however, some of the questions have been designed in a Likert Scaling format.<sup>44</sup>

Due to the novelty of the research, its complexity and the need to have a sample that is representative of the different types of households in the study area, a combination of stratified and systematic sampling strategy was applied in this research.

**Primary qualitative data:** Hastings and Perry (2000, p. 213) described this data collection method as a useful tool for understanding complex phenomena, attitudes and beliefs in less studied research areas. This exercise provided a useful tool to study the relevance of the existing appliance energy efficiency policy measures and to identify possible conflicts and

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<sup>43</sup> Raosoft is an online-based tool for sample size calculation with provisions to input key parameters and population size. The tool is available online at: [http://www.raosoft.com/sample\\_size.html](http://www.raosoft.com/sample_size.html) (Last accessed on: 12.07.2017).

<sup>44</sup> Likert scale is an ordinal response scale used mainly in questionnaires to measure levels or degrees of agreement/disagreement with a statement or sets of statements. It assumes that attitudes can be measured and respondents are offered series of pre-coded response options (McLeod, 2008, p. 1).

overlaps in institutional mandates, which has not received sufficient attention in the literature. The data collection process to evaluate conflicts and overlaps in mandates involves a critical analysis of relevant institution's mandates, activities and initiative in the area of energy efficiency. The analysis was complemented by a set of in-depth semi-structured qualitative interviews and questionnaires with key government ministries, departments and agencies (MDAs). The MDAs were identified and selected based on their mandates and role (as stipulated in the National Energy Efficiency Action plan – NEEAP) in advancing appliance energy efficiency.

The Selected MDAs are as follows:

- Federal Ministry of Power (FMP).
- Federal Ministry of the Environment (FME).
- Federal Ministry of Science and Technology (FMST).
- Energy Commission of Nigeria (ECN).
- Standards Organization of Nigeria (SON).
- National Environmental Standards and Regulations Enforcement Agency (NESREA).

The roles of the MDAs were assessed in respect to the following policy areas: policy planning and development; monitoring, verification and enforcement of appliance energy efficiency measures; advisory and support roles. These policy areas served as variables to evaluate possible conflicts and overlap in assigned institutional mandates. The interviews provided a platform to have an in-depth understanding of MDAs activities in the above enumerated policy areas and the questionnaires were employed as a form of triangulation to study the level of engagement in each of the policy areas. This data collection process also involved interviews with key informants at the local electricity distribution company in Enugu (Enugu Electricity Distribution Company – EEDC). In this case, data collection focused on key challenges in the operations of the local utility (basically electricity distribution) and to understand if the utility company is engaged in any form of utility-based end-use energy efficiency program(s). Key informant views were utilized to identify ways to overcome conflicts, overlaps in institutional mandates and also, to understand the barriers and challenges experienced with regards to the implementation of energy efficiency policies.

The interviews were planned and executed between 2014, 2016 and 2017 during research trips to Nigeria. Prior to this, permission to conduct interviews was requested through email

correspondences and ordinary mails. The first interview request was made with the Energy Commission of Nigeria (ECN) and subsequently, other identified MDAs were contacted based on a snowball sampling technique. Interview requests were mostly granted with dates scheduled accordingly. The interviews involved both with the identified MDAs, as well as international organizations working towards promoting energy efficiency in Nigeria. Majority of the federal government agencies are located in the federal capital city of Abuja and also, Lagos which thus, involved a lot of traveling from the main case study area of Enugu. The interviews were carried out using a pre-determined set of guidelines (see Appendix 2) to prompt discussions which are in line with the research questions of this dissertation. The interviews were conducted conversationally and each lasted between thirty minutes and two hours. The interviews were also recorded in audio with the approval of the interviewee and for reference purposes. The questions were answered very cordially and more lights were shed on the issues discussed. A total of ten interviews were conducted:

- **Prof. Godwin Unachukwu:** Centre for Energy Research and Development, University of Nigeria, Nsukka (08.05.2014).
- **Dr. Charles Diarra:** Head of Unit: Energy efficiency. Nigeria Energy Support Programme (NESP) Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Abuja, Nigeria (27.10.2016)
- **Mr. Sulu Ibrahim:** Deputy Director: Energy Management, Training and Manpower Development Department, Energy Commission of Nigeria (ECN) Abuja. (26.10.2016).
- **Engr. James Gana:** Senior Scientific Officer 1: Energy Management, Training and Manpower Development Department, ECN, Abuja, (28.10.2016).
- **Mr. Francis Okafor:** Enugu State Economic Planning Commission (07.11.2016)
- **Mrs. N. Nwobodo:** National Population Commission (NPC) Enugu state office (10.11.2016 and 11.11.2016).
- **Engr. O. Fatai:** Technical Assistant to MD/CEO, Enugu Electricity Distribution Company (EEDC), Enugu, (01.12.2016).
- **Mr. R. Adewumi:** Head of Laboratory: Electrical/Electronics Laboratory, Standard Organization of Nigeria (SON), Lagos (19.12.2016).

- **Mr. Etiosa Uyigüe** Project Manager, Global Environment Facility (GEF) – United Nations Development Programme's (UNDP) Nigeria Energy Efficiency Programme. Abuja (28.09.2017).
- **Mr. Festus Eguaoje:** Deputy Director, Department of Planning, Research and Statistics, Federal Ministry of Environment, Abuja. (02.10.2017 and several email correspondences).
- **Engr. Akinade Ajeigbe:** Federal Ministry of Power, Abuja (several telephone discussions and email correspondences).
- **Ibrahim Musa (Esq):** Assistant Legal Adviser/Principal State Counsel, Legal Services Department, National Environmental Standards & Regulations Enforcement Agency (NESREA) (several telephone discussions and email correspondences).

In as much as interview guidelines were used, the questions were open which ensured further discussions. The questions could be modified depending on the area of specialization of the interviewee. Questions not initially in the prepared guideline were introduced in some cases.

### **3.3.2 SECONDARY DATA**

Secondary data were collected through extensive review of peer-reviewed articles, journal publications, conference proceedings, books, grey literatures (project reports, government agency's publications, policy documents, reports of studies on similarly treated contexts, etc). Information from this data source provided the knowledge for the research background and also guided the basis for the conceptual foundations concerning energy efficiency. Furthermore, an extensive literature review of energy efficiency potential studies was carried out to understand the levels of details required, common methodologies and the necessary assumptions to be considered during modeling. This is quite pertinent in the determination of data sources and the type of primary data to obtain. The research equally relied on grey literatures and government agency publications such as the approved National Energy Efficiency Action Plan (NEEAP) and the National Renewable Energy and Energy Efficiency Policy (NREEEP) and the ECN's End-use Metering Study to gain knowledge on government's energy efficiency objectives, energy saving targets and climate goals as well as baseline energy usage in the case study area. Also, publications by international organizations in Nigeria such as the GIZ project report – Nigeria Energy Support Program (NESP) on the institutional framework, energy

efficiency planned projects, role of international organizations in advancing energy efficiency, relevant stakeholders and their scope of operations, were consulted. Publications by other various international organizations such as the United Nations (UN), the World Bank and the International Energy Agency (IEA) was relied upon to gain relevant knowledge on energy efficiency best practices and relevant data needed for modeling approaches. Finally, once the research findings were established, reference to findings from literature reviews was necessary to assess their theoretical validation.

### **3.4 DATA ANALYSIS.**

The ontological and epistemological positions of this research highlight the importance to adopt different methods of data analysis (Hakim, 2000). Quantitative and qualitative methods were adopted in the analysis of the data collected.

#### **3.4.1 QUALITATIVE APPROACH**

This data analysis method was adopted to study a principle of variation in the existing energy efficiency policies in Nigeria and to identify conflicts and overlaps in institutional mandates in respect to institutions' assigned roles for the advancement of energy efficiency in Nigeria. Studying the principle of variation in the existing energy efficiency policies was conducted by a comparative analysis of the planned and existing policy measures with internationally established and proven best practice, the integrated policy approach. The analysis is aimed at revealing the suitability of the existing and planned measures in transforming the efficiency market in Nigeria. The analysis of institutional mandates was carried out using content analysis by examining systematic differences between instances and identifying reoccurrences or duplication of roles in key institutional mandates. To perform the analysis of the institutional mandates of key institutions, the activities of key MDAs were reviewed carefully and consistently. The analysis focused on identifying variability and matching patterns or themes in the activities of each of the interviewed institutions. A matrix was developed to present a clear picture of identified overlaps in mandates and activities (see section 6.4). These exercises are aimed at addressing objectives three, four and five of the research. Figure 3.2 summarizes the top-down approach of this research.

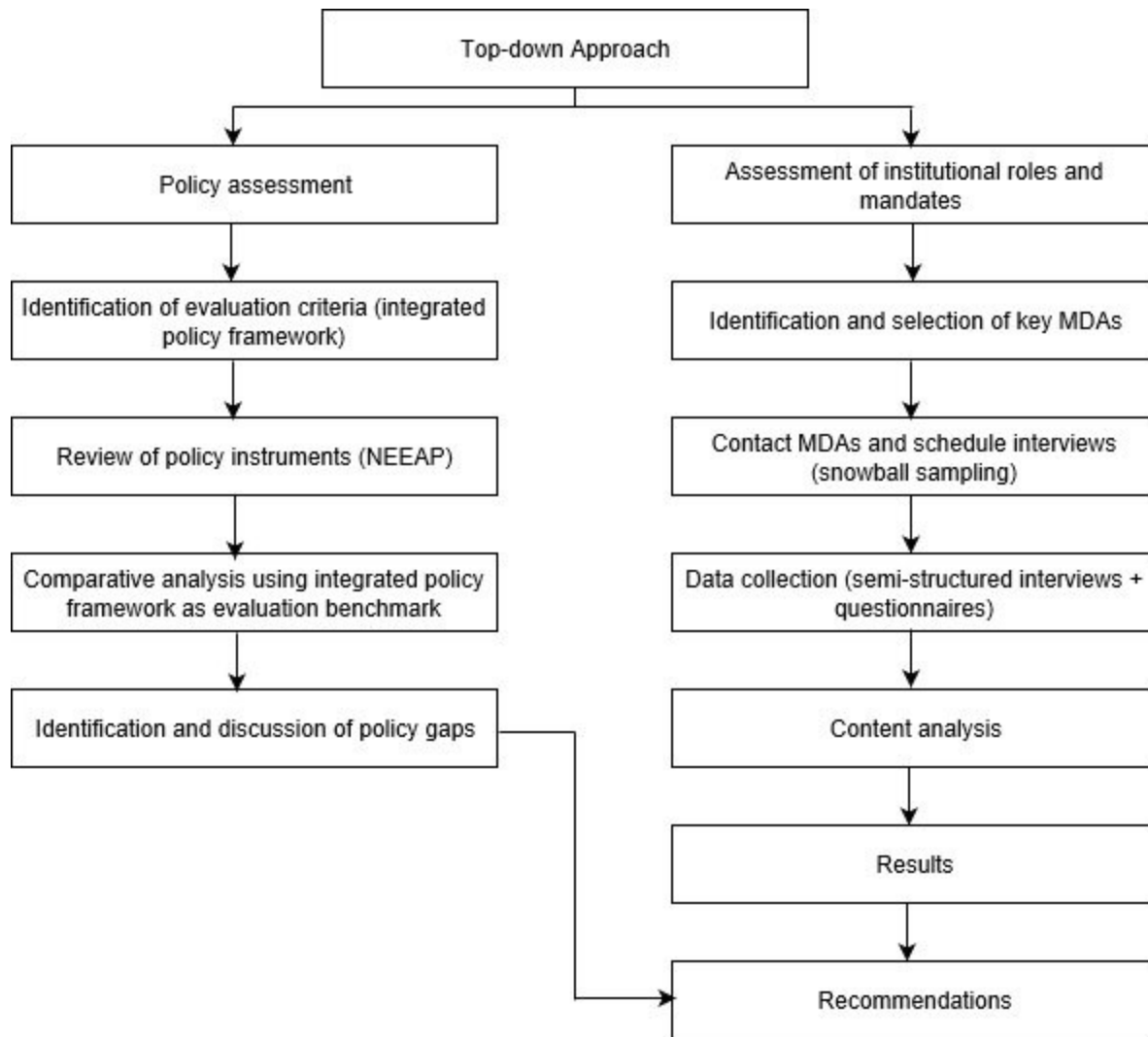


Figure 3.2 Top-down approach (Source: Produced by the author).

Data gathered from the interview with the local utility in Enugu provided information used to address objective six of the dissertation.

### 3.4.2 QUANTITATIVE APPROACH

Quantitative data analysis methods employed in this research includes a spreadsheet engineering model and statistical descriptive analysis using Excel.

**Spreadsheet modeling tool:** Policy-oriented research most often involves simulation, projection and modeling of trends (Hakim, 2000).

The LBNL-PAMS model was used to make a baseline energy use and emission projection and to estimate energy and emission savings potentials based on the conceptualized policy scenarios compared to baseline estimates. The projection is made up to 2030 and assumes a policy

implementation year of 2019. The year 2030 was chosen because of its relevance in the global policy making time frame and also, if policies are effectively implemented, this time frame will allow enough period for the turnover of the market product stock. As discussed in section 1.2.1, three scenarios have been conducted and the main policy tool used in the policy scenarios is varying levels of efficiency. The scenarios are:

- Business-as-usual (BAU) or base case scenario: The BAU scenario presents current baseline energy efficiency level and models energy use trends of the covered appliance assuming that no policy intervention action was put in place. Several socio-economic parameters (population increase, GDP growth, electrification rate) as established in Nigeria's NDC, which drives energy consumption, were taken into consideration. These adopted socio-economic parameters were used in the NDC to project national emissions levels in the absence of intervention actions. Also, data retrieved from the household survey and literature provided other baseline information employed in the modeling. In the absence of standards, the diffusion rate of inefficient appliances would be higher than desired because the market is not mandated to supply efficient type of technologies. The widespread diffusion of inefficient appliances will undermine planned mitigation actions towards the pledged emission reduction contribution in the Nigeria's NDC. However, even in the absence of standards, it is assumed that baseline efficiency in the BAU scenario would naturally improve though at a slower rate than when a definite standard is implemented. In this case, it is assumed that baseline efficiency improves at 1 % annually. This is consistent with international best practice modeling approach and ensures that potential savings are not overestimated (see U4E, 2016, p. 2).
- Policy scenario: For this research, the policy scenario models savings potential based on the current developed Nigerian MEPS for light bulbs, refrigerators and air conditioners. It assumes that all MEPS are effectively implemented in 2019.
- Aggressive Policy Scenario (APS): In this case, savings were modeled based on the assumed implementation of current best commercially available technology. It also assumes that these levels of standards are implemented in 2019. This is to ensure a uniform assessment and consistency. These products were identified based on a review



of variety of literature sources that deals on appliance engineering designs that achieve high energy efficiency levels and currently available or commercialized in more efficient markets (U4E, 2016; Letschert, et al., 2013; U4E policy guide series, 2017a; U4E policy guide series, 2017b). This engineering analysis did not consider technologies that are still in the developmental stages or products that are not yet commercialized. These selection criteria ensure that efficiency levels adopted in the aggressive policy scenario are technically feasible for any MEPS program. It is important to mention at this juncture that, considering a technical potential type of analysis, the cost-effectiveness of higher efficiency levels was not considered as selection criteria because the main purpose of the analysis is to estimate the maximum policy impact of MEPS not merely the most cost-effective option. The UEC of the best available technologies (BAT) is then simulated using the PAMS model. Engineering improvements to achieve more efficiency gains of appliances are achieved through technology innovations. For example, to meet more stringent MEPS levels for refrigerators, manufacturers have improved compressor quality, enhanced insulation to reduce heat gain into refrigerators, improved defrost mechanisms, use of gases with zero ozone depleting potential (ODP) and lower global warming potential (GWP). Light emitting diodes (LED) is also an example of improved lighting technology. Each of these innovations already exists on the market especially in developed economies but may command little or no market share in Nigeria.

Figure 3.3 represents the bottom-up approach. It summarizes the entire process of data collection leading to the analysis of collected data.

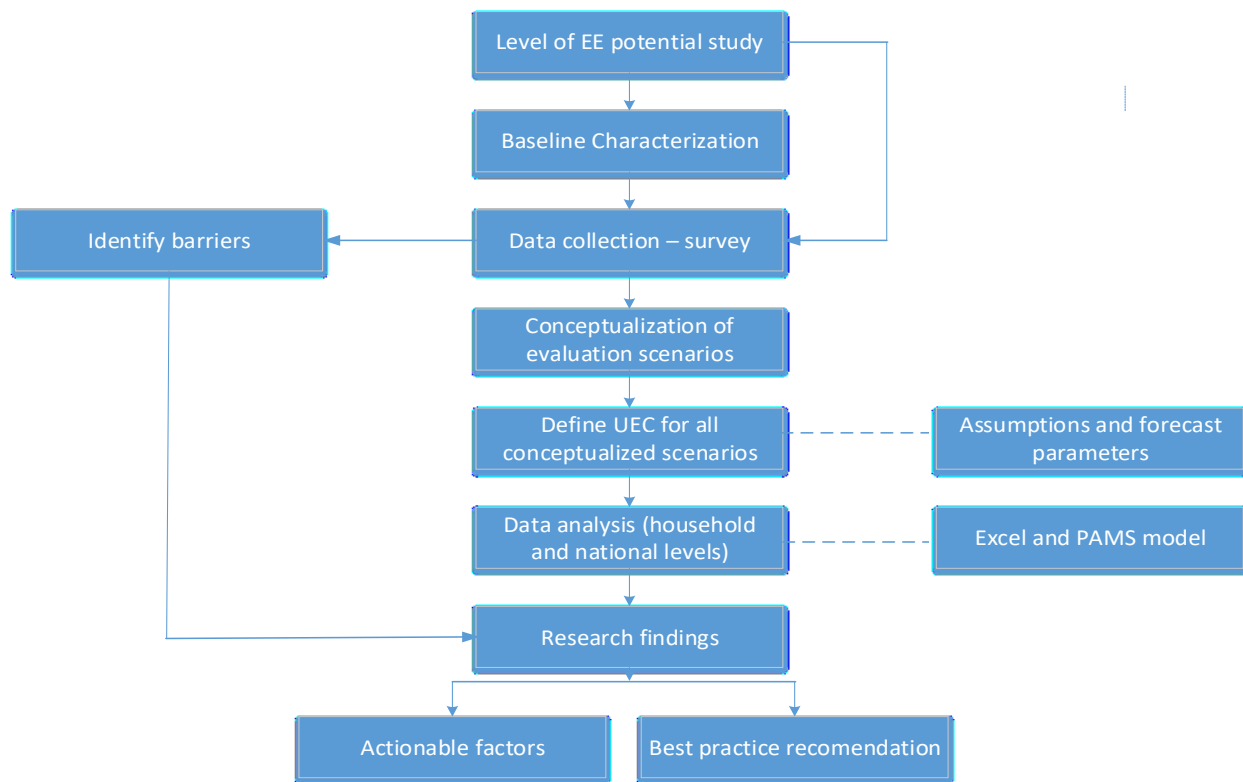


Figure 3.3 Bottom-up approach (Source: Adapted from ICF International, 2012, p. 3).

PAMS calculates national energy savings  $\Delta E(y)$  in each year of the projection period (2019 to 2030) by comparing total energy consumption (EC) of the end-use under study in the base case (BAU scenario) to that of the policy scenarios, as shown in equation 3.1:

$$\Delta E(y) = EC(y)_{base} - EC(y)_{policy} \quad (3.1)$$

Where  $EC(y)_{base}$  and  $EC(y)_{policy}$  are total energy consumptions in the baseline case (BAU) and policy scenarios respectively.

The total energy consumption is the consumption of the appliance stock in each year of the projection period. Thus the research calculates total energy consumption in year (y) according to the unit energy consumption (UEC) of the products' stock:

$$EC(y) = \sum_{age} stock(y) \times UEC(y) \quad (3.2)$$

Where:

Stock(y): Stock in year y.

UEC(y): unit energy consumption of the stock in year y.

To ensure consistency, this research assumes that the market-driven efficiency improvement that is assumed would happen in the BAU scenario (1 % energy efficiency improvement) would also take place in the efficiency scenarios; which implicitly implies that unit potential savings are constant.

The first step in assessing the potential energy savings is defining the unit energy consumption (UEC) of the products in the different scenarios. The UEC of the air conditioners and refrigerators in the policy and aggressive policy scenarios were determined based on the current Nigerian MEPS and based on the UEC of the best commercially available technologies respectively. For the baseline scenario, the UEC of the air conditioners and refrigerators is estimated according to the age of the appliance and also based on the UEC of the prevalent product type from the survey. For the light bulbs, the UEC is determined based on the observed power ratings of the light bulbs and daily hours of usage in the survey (see section 5.1).

The environmental analysis provides information on the impact of implementing appliance regulation on CO<sub>2</sub> emissions. To determine emissions reduction, energy savings results in savings of primary energy sources (natural gas) and also reduces transmission and distribution (T&D) losses. The primary energy savings (PES) is determined using the following equation:

$$PES = \frac{NES}{1 - TD} \times HR \quad (3.3)$$

TD is the amount of electricity lost during transmission and distribution<sup>45</sup> and HR is the heat rate. Country specific data on TD and HR was obtained from the International Energy Agency (IEA) and this is usually calculated from data on electricity production and consumption for a particular country.

Emission reduction or carbon dioxide emission savings (CES) in kgCO<sub>2</sub> is determined by applying country-specific emission factors (EF)<sup>46</sup> (in kgCO<sub>2</sub>/kWh) to the estimated energy savings (ΔE) derived from equation 3.1 according to the following mathematical relationship:

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<sup>45</sup> T&D losses account for losses in transmission between sources of electricity supply and points of distribution as well as in the distribution to end users (Brander, et al., 2011, p.2). The efficiency of the grid system determines the level of transmission and distribution losses.

<sup>46</sup> The CO<sub>2</sub> emission factor from fossil fuel combustion reflects the full carbon intensity of the fuel under the assumption of total oxidation of carbon in the fuel during combustion (Brander, et al., 2011).

$$CES = \Delta E \times EF \quad (3.4)$$

The emission reduction ratio (ERR) is determined from the following equation:

$$ERR = \frac{E_{base} - E_{policy}}{E_{base}} \times 100 \quad (3.5)$$

Where  $E_{base}$  is the emission of the baseline scenario and  $E_{policy}$  is the emission of the policy scenarios.

### **Basic assumptions.**

**Appliance penetration rate:** this is a factor of appliance sales and stock in the modeled market. It takes into cognizance, the changes in the appliance ownership rate within the projection period, both in the baseline case and policy case scenarios. The model assumes that the purchase and use of appliances will increase as the population and purchasing power of end-users increases. The increase in purchase will add to the existing stock and also, drive an increase in electricity demand. This increase will, however, be a gradual process because improvements in energy efficiency of products will come with an increase in appliance costs and thus, ownership rates, in principle, will be impacted especially in the short to medium-term period. It is expected that price will normalize with time due to economies of scale. It is assumed that the purchasing power of end users will increase as the economy grows. With improved purchasing power, consumers will attain a higher standard of living, requiring more comfort at home leading to the purchase of more household appliances. As a result, appliance penetration rate was modeled as a function of economic growth rate and gross domestic product (GDP) per capita. Another important factor that will influence appliance penetration rate is an increase in the electrification level. As more households are connected to the national grid, the need for appliance ownership would increase. Consequently, the impact of the increasing electrification rates is also taken into consideration within the modeling period. The appliance penetration rate is represented by the following econometric model:

$$Sat = (K \times I(y))^{\lambda a} \times [1 - e^{-(bE(y)^{\lambda b} + cU(y)^{\lambda c})}]^a \quad (3.6)$$

Where:

- Sat is appliance saturation.
- I monthly household income, given by GDP divided by the number of surveyed households.
- U national percentage of urbanization
- E national percentage of electrification
- y the year of the projected saturation

PAMS also relies on country's energy sector and engineering data such as transmission and distribution (T&D) loss factor, CO<sub>2</sub> emission factor, current prices for electricity paid by residential consumers. When available, country-specific energy and engineering data increase the accuracy of derived estimates. Table 3.1 highlights the assumed values of the considered parameters which served as input into the model. GDP of 5 % was adopted in line with the economic scenario applied in Nigeria's NDC report. This will provide consistency in benchmarking results from the research with estimated targets reached in the NDC. The 5 % economic growth rate in Nigeria's NDC report is based on GDP data for 2010 to 2014 (Nigeria NDC report, 2017, p. 9).

Table 3.1 Forecast parameters

Parameters	Value/Growth rate	Source
Total Population (2017 estimate)	190,886,311	World Bank data, 2018
Population growth	2.6 %	World Bank data, 2018; Nigeria NDC report
Total population 2030	264,068,000	World Bank data, 2018
Gross Domestic Product (GDP) growth	5 %	Consistent with economic growth rate scenario adopted in the analysis reported in the Nigeria's NDC report.
GDP per capita (US\$)	2,950	2014 value (Nigeria NDC report)
Income growth	1.4 %	Forecast based on historical trend of national growth rates from 1990 to 2050 by the Intergovernmental Panel on Climate Change (IPCC)
Current electrification rate (2016 estimate)	59.3 %	World Bank data, 2018
Electrification level	82 % in 2030	Based on model forecast.
Annual electrification growth rate	1.2 %	Research based estimate
T&D loss factor	9.8 %	Based on IEA published value
CO <sub>2</sub> emission factor	0.43963136	Country specific data. Based on published values (Brander, et al., 2011, p. 6)
Electricity price in Nigerian Naira (NGN) (Per kWh)	30.93	Based on prevailing tariff class (R2S) <sup>47</sup> in the surveyed households (EEDC, 2016)
Annual average growth rate of lighting stock	3.9 %	Based on forecast from the UN en.lighten programme
Annual average growth rate of refrigerator	5.7 %	Model estimate based on input economic parameters
Annual average growth rate of air conditioners	2.8 %	Model estimate based on input economic parameters

<sup>47</sup>The Nigerian Electricity Regulatory Commission (NERC) approved tariff charges (NGN/kWh) for EEDC tariff classes in 2017 for residential households are: R1 (4.00); R2S (30.93); R2T (34.28); R3 (48.12); R4 (46.08). The categorization of the tariff classes is based on household electricity demand level; for instance, R3 demand level ranges from > 45 kVA < 500 kVA and R4 ranges from > 500 kVA < 2 MVA (EEDC, 2016).

Based on the input economic parameters, the model forecasted 82 % electrification rate in 2030 from the current electrification rate of 67 % (2018). The choice of the values in table 3.1 was guided by relevant publications on country-specific data as illustrated in the table.

Another important parameter taken into consideration in the modeling is the appliance lifetime. The appliance lifetime determines the retirement of the products in the stock. It is factored into the stock forecast. Table 3.2 presents the useful lifetime of the products modeled in this research which is consistent with best available market information as described in the literature.

Table 3.2 Life time assumed for covered products

<b>Products</b>	<b>Lifetime</b>
Refrigerator (years)	15
Room air conditioner (years)	12
Incandescent lamp (hours)	1,000
Compact fluorescent lamp (CFL) (hours)	6,000
Light-emitting diode (LED) (hours)	15,000

Source: U4E policy guide series, 2017a, pp. 20, 21 and 26; U4E, 2016, pp. 2, 4.

Lighting stock is available through the United Nations En.Lighten initiative (En.Lighten, 2012). Stock data for air conditioner and refrigerator were taken from the United for Efficiency (U4E) market data for Nigeria (U4E, 2016). The stock data were used as direct input into the model and based on the economic growth parameters; the model forecasts a stock turnover rate of 5.7 % for refrigerators and 2.8 % for air conditioners. The forecast is used in the PAMS to calculate yearly energy consumption of the stock (i.e. the number of units in use in a given year) with consideration to shifts in the market share of efficiencies as a result of the MEPS program and equipment turnover.

The stock estimates in 2025 and 2030 are highlighted in corresponding sections that deals with the assessment of potential savings of each of the end-use analyzed in this research (see chapter 5).

For the emission reduction impact, the key assumption is that energy source for the generation of electricity during the modeling period will mainly come from natural gas with a 10 %

renewable energy contribution to the national energy mix. This is also based on the targets of reaching a 10 % renewable energy electricity in 2030 as detailed in the NEP. Taking renewable energy contribution in electricity generation into consideration will limit overestimation of emission reduction impacts of the MEPS program.

Figure 3.4 is a diagrammatical representation of the overall research framework. It highlights key aspects of the research objectives and the data source and sampling techniques employed to study each of the objective and the adopted research tool to analyze and address each of the research objectives.



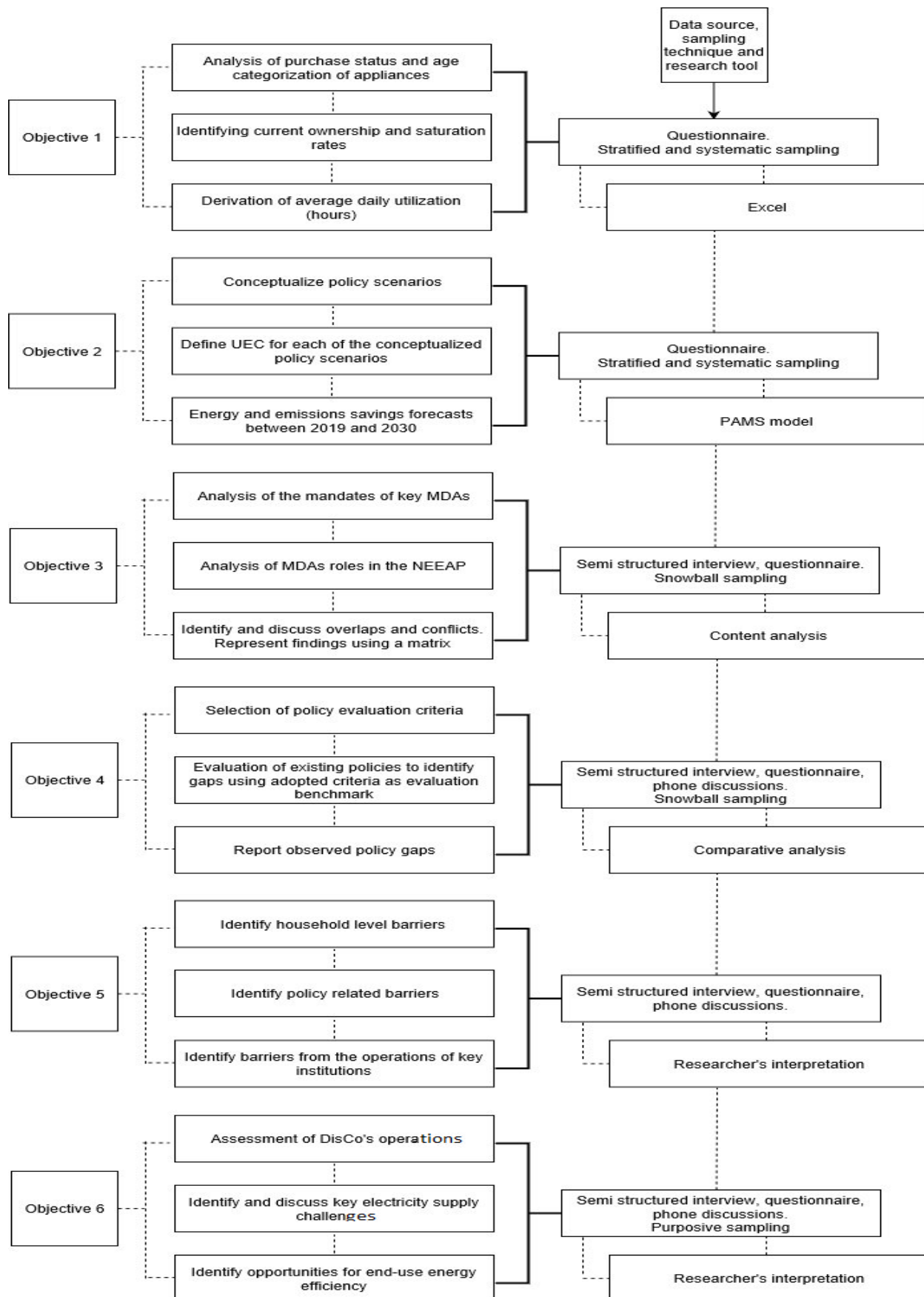


Figure 3.4 Overall research framework (Source: Produced by the author).

## **4. OVERVIEW OF NIGERIA AND STUDY AREA**

### **4.1 INTRODUCTION TO CHAPTER FOUR**

This chapter presents an overview of Enugu as well as Nigeria. It takes its departure by presenting the country's global location, geography, climatic features, enumerating aspects relevant to the research and the study area. It further depicts the national demography highlighting the peculiar features significant to the studied region and briefly explains the political situation in the country. The economy is also presented to underscore the major economic activities and potentials in the country and the studied site. It discusses the strategic position of Enugu in the overall context of the Nigerian economy. The chapter also discusses the energy situation focusing on electricity and power generation in respect to the effects of unreliability of electricity supply to households' acceptance of the overall notion of energy efficiency. It expresses the role of energy efficiency in improving access to electricity and the need to bridge the policy gaps needed to advance energy efficiency. Secondly, it also points to the major environmental problems in the case study area as observed from recently published studies on Nigeria and how these problems could be worsened by the impact of climate change. The chapter concludes by highlighting the need for developing measures to enhance low carbon and sustainable economic development.

### **4.2 LOCATION AND GEOGRAPHY**

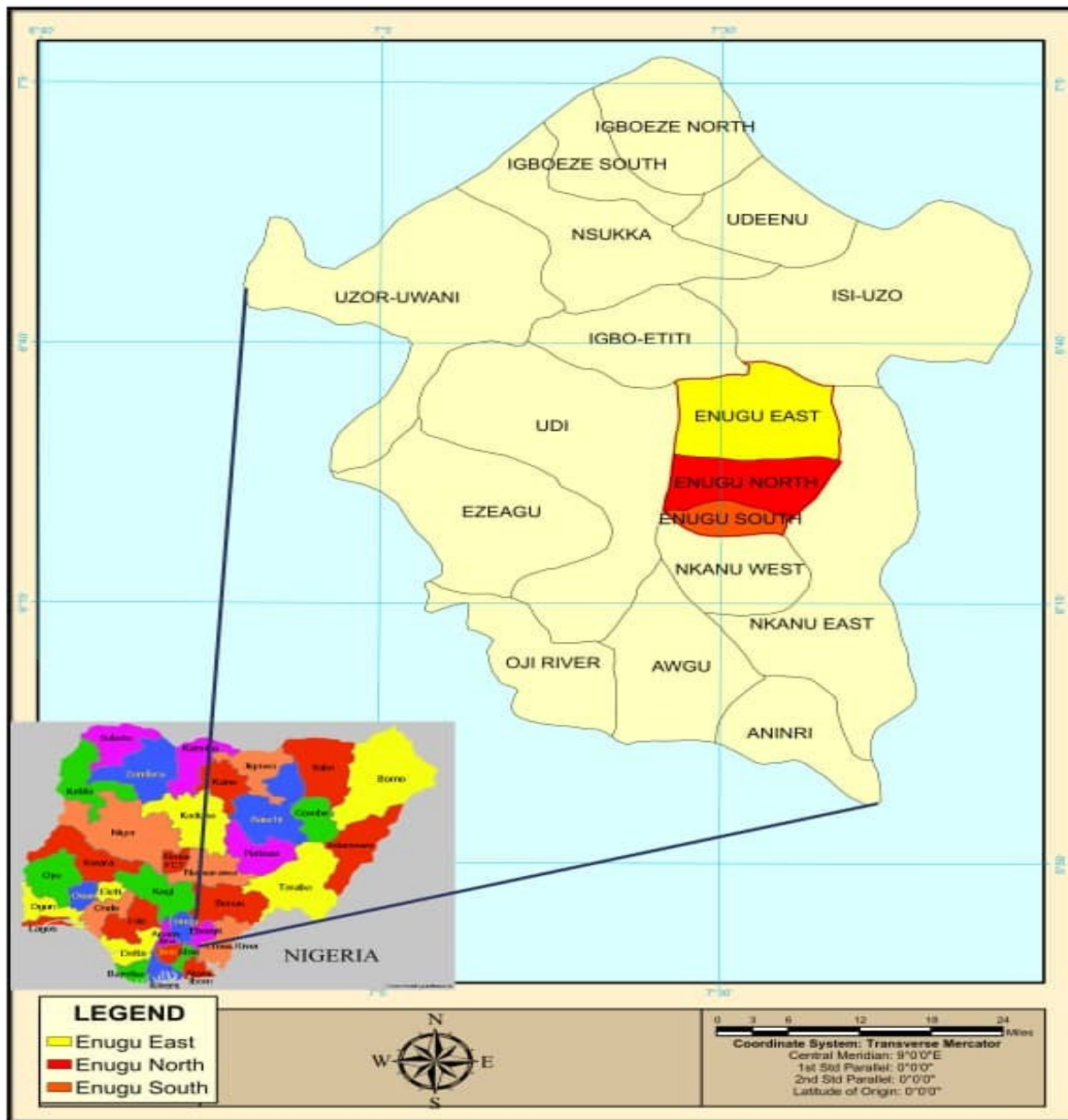
The Federal Republic of Nigeria is a federal republic that is made up of thirty-six states and the Federal Capital Territory at Abuja. Nigeria is located in West Africa, sharing borders with the Republic of Benin in the west, the Niger Republic in the north, Chad and Cameroon in the east, whilst to its south is the Atlantic Ocean running along the Gulf of Guinea. Nigeria lies between latitudes 4°N and 14°N and longitudes 2°E and 15°E. Nigeria measures approximately 1,050 km from north to south and 1,200 km from east to west (GIZ, 2015, p. 18). The country covers a surface area of 923,770 km<sup>2</sup> and has a coastline of 853 km (World Bank Data, 2018).<sup>48</sup> The topography ranges from lowlands along the coast and in the lower Niger Valley to high plateaus in the north and mountains around the eastern region. Nigeria is administratively divided into six geopolitical zones; the North-Central, North-East, North-West, South-East, South-South, and

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<sup>48</sup> World Bank data on Nigeria available online at: <https://databank.worldbank.org/data/reports.aspx?source=2&country=NGA> (Last accessed on: 21.04.2019).

the South-West. The ecology of the country varies from tropical forest in the south through savannah to the sub-Sahel zone in the far north.

The case study area of Enugu is in the South-East geopolitical zone of Nigeria. It is located at 6°30' north of Equator and 7°30' east of Longitude (ESG, 2016, p. 8). It shares borders with Abia and Imo states to the south; Ebonyi to the east, Benue to the north-east, Kogi to the north-west and Anambra state to the west. Enugu state covers an area of 7,161 km<sup>2</sup> and in respect to land area, it is ranked 29<sup>th</sup> out of the 36 states in the federation (ESG, 2016, p. 8). There are a total of 17 local government areas in Enugu state and this research is focused on the three local government areas in Enugu-Urban (Enugu-North, Enugu-South and Enugu-East). Figure 4.1 shows the map of Nigeria, highlighting the position of Enugu state and showcases the case study areas.



**LOCATION MAP OF STUDY AREA**

Figure 4.1 Map of Enugu state highlighting case study areas (Source: Author).

### 4.3 CLIMATE

Nigerian temperatures are relatively high (with averages around the mid-thirties Celsius). There are insignificant variations in seasonal and diurnal ranges. Nigeria has two main seasons, namely, the rainy (wet) season (usually starts from April till late October) and the dry (Harmattan) season (which starts from early November till around late March).

Harmattan winds and dry chilly spell ushers in the dry season. The season, which normally lasts till February, is characterized with lower temperatures and dust winds which are brought by the north-east trade winds from the Arabian Peninsula across the Sahara (GIZ, 2015, p. 19). The Nigerian Energy Support Programme (NESP) report commissioned by the GIZ, referred to the period from February till March as the second phase of the dry season and also, the hottest period of the year associated with high temperatures ranging from 33°C to 38°C (GIZ, 2015, p. 19). The hottest month in Enugu is February with temperatures of 31°C, while the lowest of 16°C are recorded around November/December (ESG, 2016, p. 8). There is a significant variation in total annual rainfalls across the nation. The South-South records the maximum total precipitation (basically around the coastal area of Bonny and east of Calabar) characterized with a mean annual rainfall of more than 4,000 millimeters (mm) (GIZ, 2015, p. 19). Enugu records mean annual rainfall of around 1840 mm (GIZ, 2015, p. 140). The lowest rainfall period in Enugu is the month of February while July records the highest rainfall (ESG, 2016, p. 8). Nigeria is classified into five different climatic zones: Tropical rain-forest climate in the South-South and some part of South-West, Tropical monsoon climate in the South-South and part of the South-East and South-West, Tropical wet and dry or Savanna climate (Enugu falls under this climate classification and the North-central), Hot desert climate in the North-East and the hot-semi-arid climate in the North-West and some part of the North-East (GIZ, 2015, p. 19).

#### **4.4 DEMOGRAPHY**

Nigeria's 2015 population was estimated at 182 million (World Bank Data, 2018).<sup>49</sup> It is regarded as Africa's most populous nation and the eighth-most populous nation in the world. The national population is projected to grow at an annual rate of 2.6 % in the next 20 years and the population is thus, forecast to grow to 264,068,000 people by 2030 (World Bank Data, 2018; GIZ, 2015, p. 21). From the Nigeria's NDC report, about 30 % of the population were categorized as living below the international poverty line of United States Dollars (US\$) 1.25 per day in 2014 (Nigeria NDC report, 2017, p. 1). According to the GIZ' NESP report, half of the population live in urban areas (GIZ, 2015, p. 21). There are variations in the population distribution across the

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<sup>49</sup>Data available online at: <http://databank.worldbank.org/data/reports.aspx?source=2&country=NGA> (last accessed on: 21.04.2019).

states. The semi-arid North-Eastern and North-Western states have relatively less dense population than states in the South-East where population densities are usually high. The population of Enugu for 2015 was projected at 4,331,318 and it is also rated as densely populated with 460 persons per square kilometre (km<sup>2</sup>) (ESG, 2016, p. 8). Table 4.1 expresses the specific demographic features of the case study areas showing 2015 estimated population with poverty count and percentage poverty level.

Table 4.1 Poverty ranking of Enugu State

<b>Enugu State</b>			
Local Govt. Area (LGA)	Population of LGA	Poverty count	Percentage (%) of population
Enugu East	232,791	49,602	21
Enugu North	589,788	81,322	14
Enugu South	222,203	51,129	23

Source: World Bank poverty mapping in Nigeria, 2015.

Table 4.2 is a quick overview of the physical and socio-economic characteristics of Nigeria.

Table 4.2 Physical and socio-economic characteristics of Nigeria

Base year	2015
Population	190,886,311 (2017 estimate)
Total area (km <sup>2</sup> )	923,770
Land coverage (km <sup>2</sup> )	910,835
Water coverage(km <sup>2</sup> )	12,933
Forest area (km <sup>2</sup> )	69,930
Perimeter (km)	4,047
Coastline (km)	853
Population growth (annual %)	2.6
Population density (people per km <sup>2</sup> of land area)	200.1
Urban population (% of total)	49.4 (2017 estimate)
Urban population growth (annual %)	4.2 (2017 estimate)
Adult <sup>50</sup> literacy (% of people aged 15 years and above)	51.1 (2008 estimate)
Electricity production from natural gas (% of total)	82.4 % (2014 estimates)
Electricity production from hydro sources (% of total)	17.6 % (2014 estimates)
CO <sub>2</sub> emissions (metric tons per capita)	0.6 (2014 estimates)
Emissions (% of global total)	< 1 % (2010 estimate)
Poverty headcount (% of population)	30 % (2015)
Access to electricity (% of population)	59.3 (2016 estimate)
Electric power consumption (kWh per capita)	145 (2014 estimate)
GDP per capita (current US\$)	2950 (2014 estimate)
GDP growth (annual %) <sup>51</sup>	5 %

Source: World Bank data, 2018; GIZ, 2015; Nigeria NDC report, 2017.

#### 4.5 POLITICAL SITUATION

Since 1999, Nigeria has been consolidating its democratic process (a transition from a long period of military regime). In February 2019, the nation conducted its sixth national democratic election since returning to democracy in 1999. On the international scene, Nigeria continues to

<sup>50</sup> Adult refers to ages 15 and above (World Bank Data, 2018).

<sup>51</sup> GDP growth is based on the projections established in the Nigeria's NDC report.

play key significant roles in the African Union (AU), Economic Community of West African States (ECOWAS), and the New Partnership for Africa's Development (NEPAD) among others.

#### **4.6 ECONOMY**

About 70 % of the population in the South-East state of Enugu engages in farming activities (18 % and 12 % engage in trading and services respectively) (ESG, 2016, p. 28). Due to its location within the tropical rainforest and savannah belt, the state is endowed with rich agricultural lands appropriate for growing most tropical based cash and food crops. The main agricultural products are rice, cassava, maize, yam, cocoyam and a local variety of beans – the black beans; also, palm oil, cashew and pineapple (ESG, 2016, p. 28). The processing of agricultural products (especially, pineapple, palm oil, rice and cashew), presents huge investment opportunities (ESG, 2016, p. 29). There is a huge deposit of coal in Enugu state which has earned it the name, “The Coal City State”. The state is also endowed with other mineral resources such as iron ore, petroleum, natural gas, clay and limestone. The state plays a significant role in the economy of Nigeria; in respect to Internally Generated Revenue (IGR),<sup>52</sup> it was placed in the third and fourth positions out of the 36 states in Nigeria for the years 2013 and 2014, respectively (ESG, 2016, 25). In 2015, Enugu was rated as one of the 100 most resilient cities in the world by The Rockefeller Foundation ranking.<sup>53</sup>

#### **4.7 ENERGY AND ENVIRONMENTAL PROBLEMS**

The poor access to reliable energy supply (the case for grid-connected electricity) has resulted in situations where households use own fossil-based power generating sets as an alternative to grid electricity supply, which also exacerbates environmental emissions. The estimated current installed capacity of the national grid is approximately 13 gigawatts (GW) but in 2015, only a generating capacity of 6.8 GW was recorded due to poor grid infrastructure as well as, poor maintenance of the generating power stations (GIZ, 2015, p. 33). Almost all the respondents during the survey do not have steady electricity supply up to 24 hours and this is a general case

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<sup>52</sup> IGR accounts for 30 % of the total resource envelop of the state (ESG, 2016, p. 25).

<sup>53</sup> The ranking rates cities in terms of their capacities to respond to social, economic and physical challenges and stresses that are characteristics of the 21<sup>st</sup> Century. The cities are expected to serve as a model for other global cities that seek to enhance their own resilience (The Vanguard News, 2014 available online at: <http://www.vanguardngr.com/2014/12/enugu-makes-history-joins-worlds-100-resilient-cities/100ResilientCities.org>).



in the country and may present a crucial challenge against the advancement of energy efficiency in Nigeria. Most of the respondents were of the notion, “why save electricity that is not even available – we cannot save what we do not have”. This also serves as an indication of the low level of awareness and/or understanding of the idea of energy efficiency as observed in the case study area and begs for the need to enhance awareness creation that energy efficiency can actually alleviate the issue of unreliability of electricity supply because electricity saved can be made available to other areas thus improving supply.

The poor electricity supply also has resulted in the use of other sources for lighting in households such as candles and kerosene-based lanterns. The use of these light sources has been associated with several health issues such as deteriorating eye sights and the exposure to gases that are hazardous to the human body. They have also been linked to the cause of several fire incidences destroying homes and properties. There seems to be an increasing recognition of energy efficiency as a resource in Nigeria. The government has embarked on several measures to advance energy efficiency including the draft and approval of several related policies (such as the NREEEP approved by the Federal Executive Council in 2015) and the introduction of MEPS for appliances (light bulbs, refrigerators and air conditioners have been covered so far). Nigeria’s NDC highlights energy efficiency as part of key measures to reduce energy use and mitigate emissions from the energy sector. The government targets a 2 % increase per year up to 2030 (30 % by 2030) (Nigeria’s NDC report, 2017, p. 2). It is expected that this measure, if properly implemented, will assist in addressing electricity reliability issues and reduce the incessant use of fossil-based power generating sets.

The major environmental problems in Nigeria are the occurrence of devastating floods and rising sea levels in the coastal region and droughts and desertification around the Sahelian north (Ekpoh, 2014, p. 21). Recent incidences of these environmental problems include; the flooding in Lagos, Ibadan and Calabar (all in 2011) that destroyed properties, resulted in deaths and rendered many homeless; similar occurrence in 2012 in Makurdi, Lokoja and Yenegoa; the reported abnormal dust storm that enveloped the entire nation for a period of one week in March 2010, which led to the cancellation of several local flights; the floods in Sokoto in 2010 that washed approximately 20 villages away, displaced 130,000 people, killed six persons and destroyed many farmlands (Ekpoh, 2014, p. 20). There have been observed cases of flood and

soil erosion in several parts of the South-East region which also devastate farmlands and road networks (Nigeria's NDC report, 2017, p. 5). Some unwholesome practices such as illegal logging or deforestation for wood-powered cook stoves are part of the problems that intensify desertification in the northern region. The impacts of climate change will also exacerbate these conditions if adequate mitigation and adaptive measures are not properly and timely implemented. In the residential sector, rising temperatures (associated with climate change) would result in increased energy demand for cooling. In line with these arguments, there is a need to implement mitigation measures that will promote a low carbon economy and as well, enhance sustainable economic growth.

## **5. RESIDENTIAL SURVEY – DATA ANALYSIS**

### **5.1 INTRODUCTION TO CHAPTER FIVE**

Between July and December 2016 and July to November 2017, the researcher conducted a household survey of residential energy use and appliance ownership patterns in Enugu. A total of 384 households in Enugu urban metropolis were contacted. 320 questionnaires were retrieved and after the evaluation of retrieved questionnaires, 295 responses were considered to be of statistical significance for further analysis. The survey requested respondents to provide relevant information about their appliances, which the analysis is presented here. The contacted households are all served by the national grid.

Data obtained also provided useful insights as input data required to model the impacts of MEPS. The bottom-up quantitative analysis presented in this chapter addresses objectives one, two and part of objective five of this research.

### **5.2 DESCRIPTIVE STATISTICAL ANALYSIS**

#### **Household characteristics and energy efficiency awareness**

From the survey analysis, 67 % (representing approximately 198 respondents) are male. 41 % or approximately, 121 respondents fall within the age bracket of 40-49 (see figure 5.1).

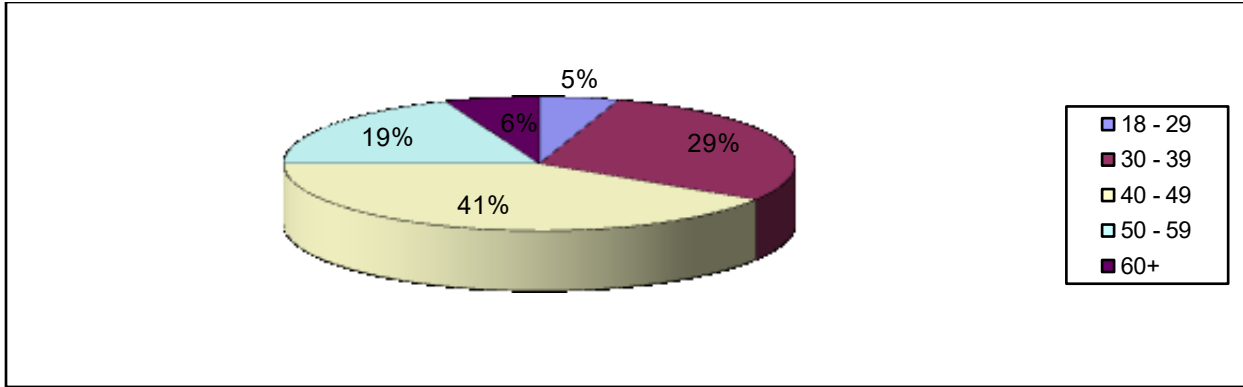


Figure 5.1 Age distribution of respondents (Source: Author)

Figure 5.2 shows the education level of respondents. 39 % or 115 respondents have education up to the university level. However, just a few (13 %) or 38.4 respondents have only basic primary education.

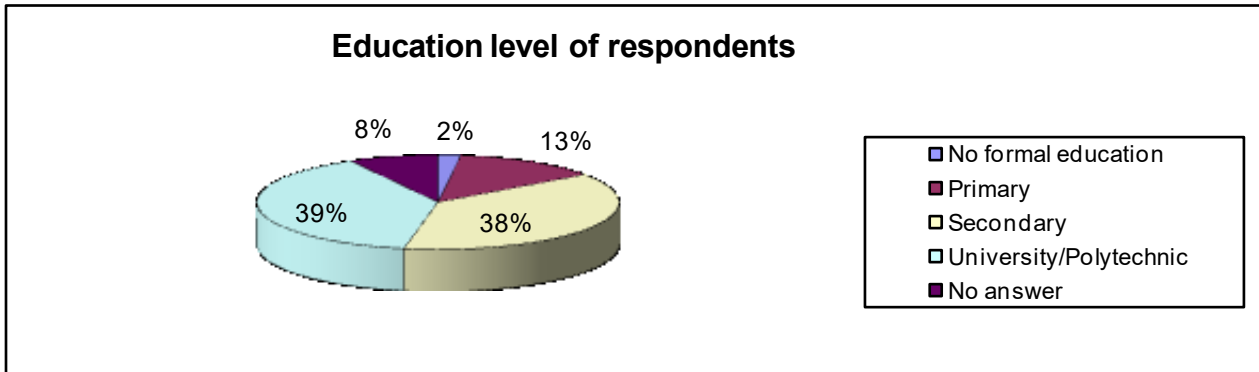


Figure 5.2 Education level of respondents (Source: Author)

In respect to respondent's occupation, Figure 5.3 shows that 31 % (approximately, 92 respondents) in the studied area reported they are self-employed (ranging from personal businesses to retail and street vendors) while around 27 % work in the public sector especially federal and state governments' civil service.

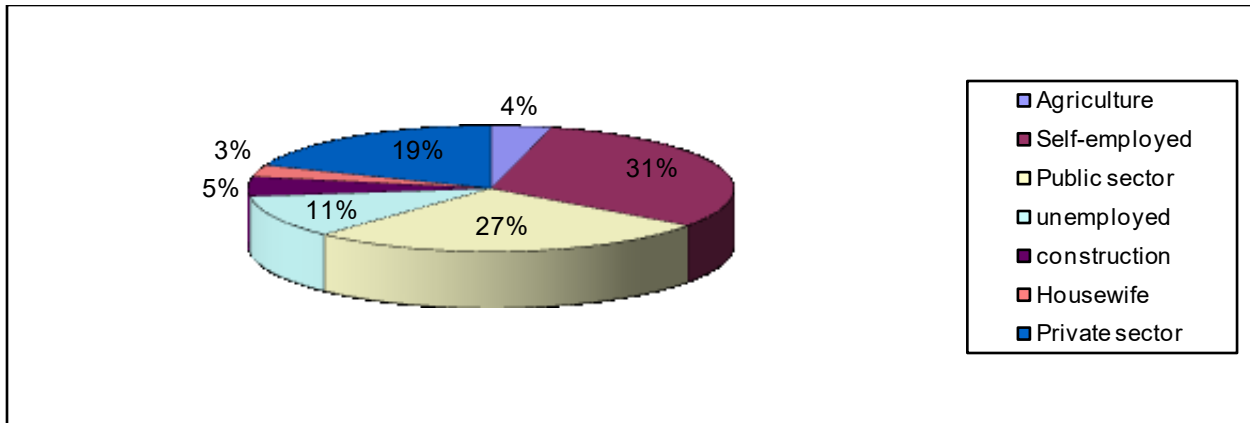


Figure 5.3 Occupation distribution of studied area. (Source: Author).

The occupation distribution seems not to be consistent with the overall predominant occupation in the state as reported in the publication of the Enugu state government (ESG) which highlights that the majority of the people are engaged in farming (ESG, 2016, p. 28). However, the occupation distribution as reported in this research can be interpreted as representing urban occupation since all the surveyed households are in the urban area. The number of unemployed respondents is only a proxy and does not represent the unemployment level of the entire metropolis. This number may also contain students.

In regards to decisions on electricity, around 27 % of the households indicated they make decisions jointly within the families while more than half of the respondents (54 %) make electricity consumption decisions by themselves.

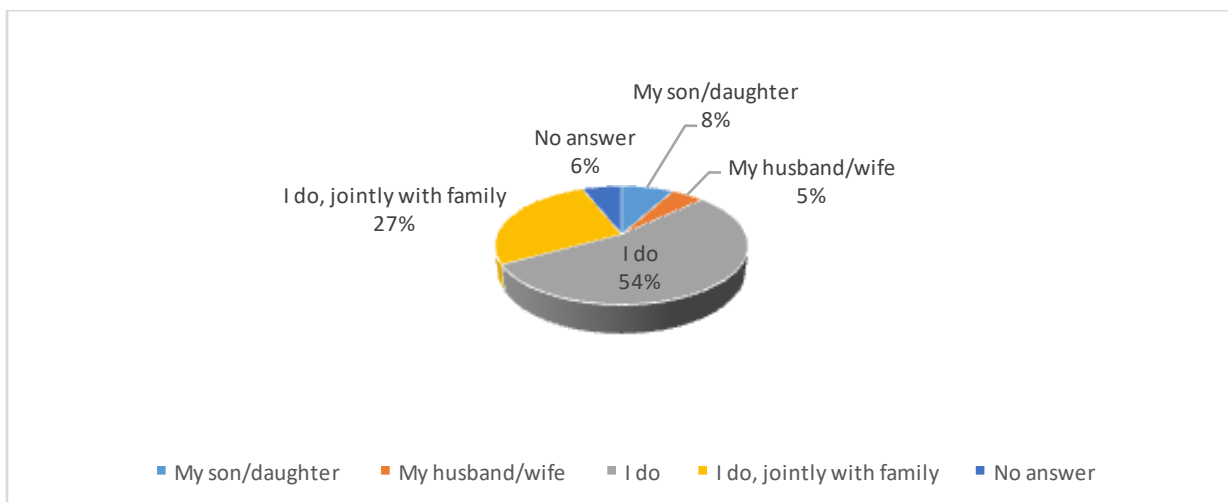


Figure 5.4 Household decisions on electricity consumption (Source: Author)

The decision making on household electricity consumption, in this case, represents options on electricity use patterns (such as reminding household members to switch off lights when not in use, etc) and buying and/or replacement of household appliances. About 61 % or 180 respondents reported that electricity is available for one to six hours per day, while 21 % (62 respondents) claimed they have electricity for an average of six to twelve hours per day; 7 % reported that electricity is available for more than 12 hours per day (see figure 5.5).

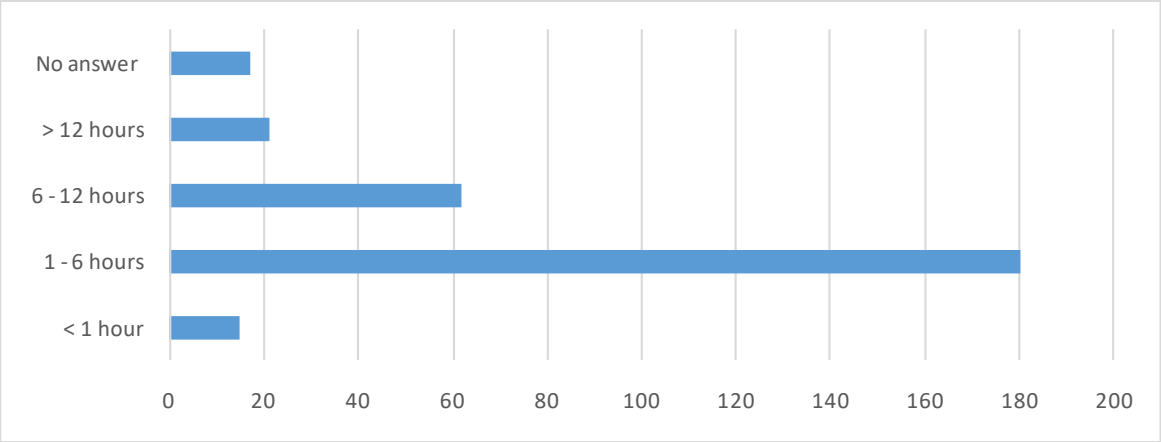


Figure 5.5 Average duration of electricity availability in surveyed households (Source: Author)

Energy efficiency awareness level in the case study area was assessed by asking respondents to indicate factors that greatly influence their choice of appliance. Only 15 % indicated they consider the overall operational cost of appliance usage before purchase while more than half of the respondents (55 %) claim that appliance initial cost plays a critical role in their decision of the type of appliance to buy.

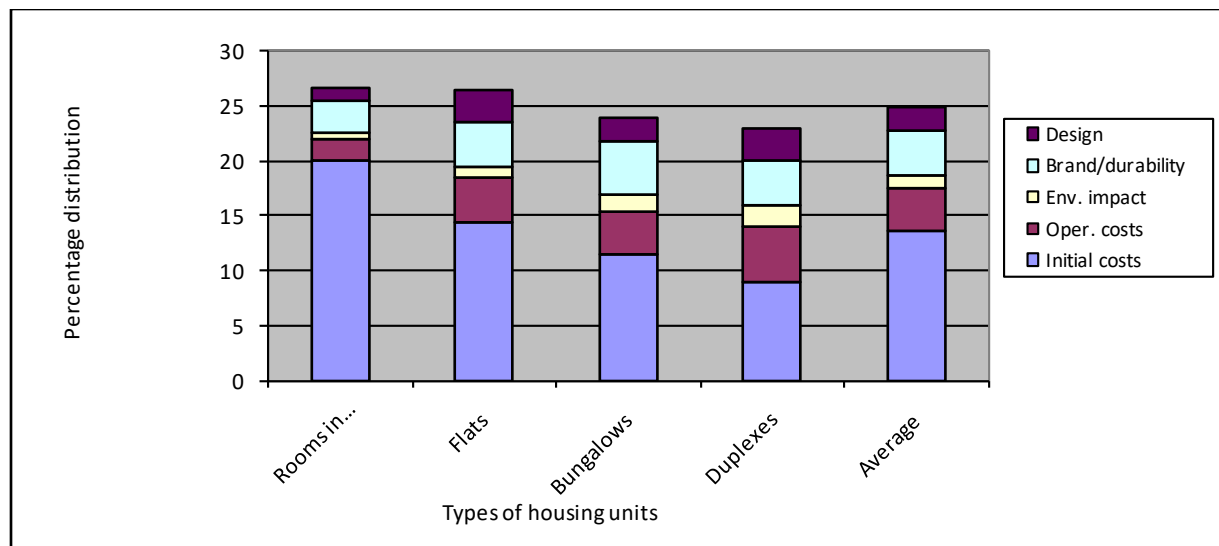


Figure 5.6 Factors that influence consumers' choice of appliance (Source: Author).

The result on factors that influence household choice of appliance was disaggregated into the various types of housing units (figure 5.6) and from the graph, most of the respondents that consider the environmental impacts of appliance use (2%) live in duplexes. Likewise, majority of those that take the overall operational cost of appliance usage into consideration also live in duplexes and bungalows. Most of the respondents (20%) that consider appliance initial costs when making purchase decisions live in the type of housing units classified as "rooms in buildings". Giving a direct interpretation of these influencing factors would mean that it is more likely to find end-users with more understanding about the concept of energy efficiency in housing types such as duplexes and bungalows. This could be attributed to the fact that these types of housing units are usually occupied by those regarded as "living above average". However, for end-users, MEPS means that all appliances available in the market for purchase meet minimum energy performance target and importantly, MEPS will deliver significant energy savings and emissions reductions irrespective of whether or not consumers factor-in energy efficiency into their purchase decisions. However, when respondents were asked if they will be willing to pay more for a product initially if it would cost less money to run, about 87% of the respondents claimed they would be willing to pay high initial costs for products if the operation of the product will result in lowering of energy costs and 8% did not accept willingness to pay high initial cost even though the appliance could result in lowering overall operational costs. About 5% did not provide any response.

Figure 5.7 shows the result of the investigation on the source of information that may greatly impact end-users’ decision to purchase an energy-efficient appliance. The result depicts that information or recommendations from friends, families and neighbors play a significant role in respondents’ purchase decisions as 32 % of respondents claim they consider such information more reliable. This could be explained from the perspective that neighbors or friends and families that have used the particular appliance or brand name should be in a better position to render advice based on their personal experiences of the product in question. 28 % of the respondents claim they rely on advice garnered from retailers. Media adverts and web-based information also provide a considerable level of influence on respondents’ purchase decisions.

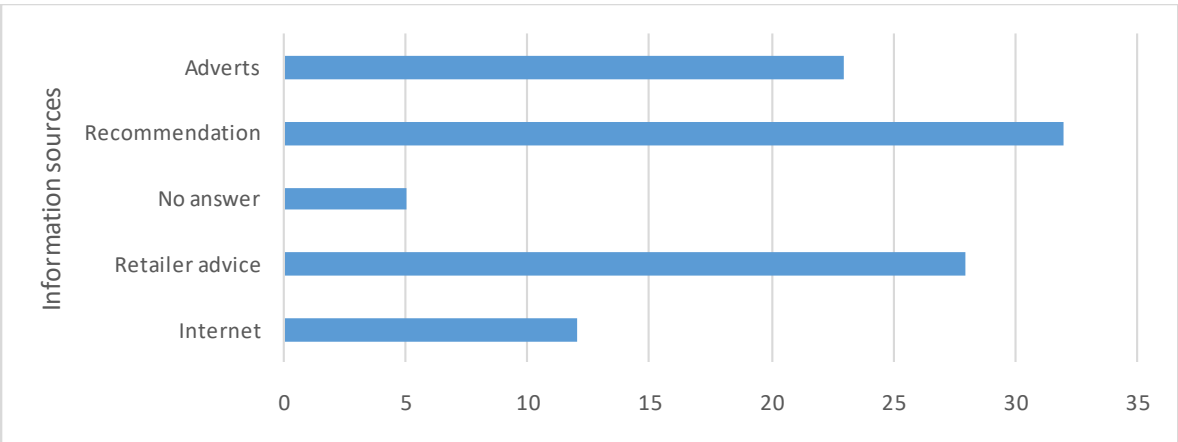


Figure 5.7 Information sources that may influence consumers’ purchase decision (Source: Author)

In reference to question B07 of the questionnaire (see appendix 1), 213 respondents indicated their electricity billing method out of which 25 % (approximately, 53 respondents) claimed they have pre-paid meters. The majority of these respondents (46 % or 98 respondents) indicated that they are on conventional meters or post-paid billing method, while 29 % or approximately, 62 of these respondents claimed they are billed based on estimates (figure 5.8).

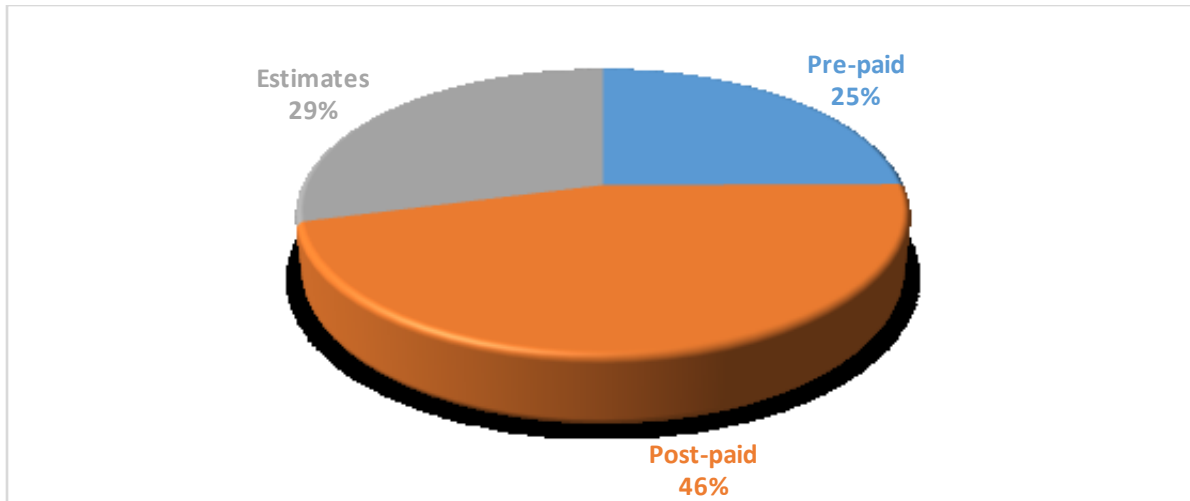


Figure 5.8 Electricity billing methods (Source: Author)

## 5.3 CALCULATION OF POTENTIAL POLICY IMPACTS

### 5.3.1 LIGHTING

The basic types of residential lighting sources in the surveyed area are the incandescent bulbs (popularly referred to as yellow bulbs by locals because of its yellowish glow) and compact fluorescent lamps (CFLs). Many of the respondents are not familiar with the term CFL, but rather energy bulbs are commonly used to refer to CFL light bulbs which are also gradually gaining the attention of the locals, though at a very slow diffusion rate. Incandescent bulbs represent around 75 % (or 1440 light bulbs) of the total recorded light bulbs and 25 % of the lamps are CFLs (representing 486 light bulbs).

Incandescent light bulbs come in a variety of wattage groups. The most common wattages in the case study area are the 40 Watts (W), 60 W and the 100 W. Incandescent lighting comprises of two basic components namely, the lamp (bulb) and a socket. The most prevalent power ratings of CFLs in the studied area are the 15 W, 20 W, 26 W and 36 W. CFLs consists mainly of three major components, the lamp, lamp base and the ballast. Fluorescent light bulbs (fluorescent tubes) does not represent a significant proportion in the surveyed households. Table 5.1 shows the distribution of incandescent light bulbs, in the surveyed households, according to their power ratings.



Table 5.1 Distribution of incandescent light bulbs by power ratings (Source: Author)

Power ratings in Watts (W)	Number of bulbs	Percentage (%)
25	22	1.5
40	358	24.8
60	1044	72.3
100	20	1.4
<b>Total</b>	<b>1444</b>	

From table 5.1, the most prevalent wattage type of incandescent bulbs is the 60 W representing about 72 % of the total reported incandescent bulbs in the visited households.

Calculating the impacts from standards for lighting in the studied area will require defining the baseline unit energy consumption (UEC) for lighting in the surveyed households and the UEC of the corresponding replacement of the market efficient promoted lamps (in this case CFLs since the Nigerian MEPS for lighting covers only CFL at the moment).

Due to the skewed nature of the data on power ratings of the incandescent bulbs, calculation of the weighted average is necessary to determine a proxy power rating value for the incandescent lamp types which will be used to determine the baseline UEC for lighting. Also, the proxy power rating is needed to identify the ideal CFL replacement for the incandescent light bulbs.

The weighted average ( $A_w$ ) is derived from the following equation:

$$A_w = \frac{(A_1 \times B_1) + (A_2 \times B_2) + (A_3 \times B_3)}{\sum B_1 B_2 B_3} \quad (5.1)$$

Where:

$A_1, A_2, A_3$  is the observed prevalent power ratings of the incandescent bulbs

$B_1, B_2, B_3$  is the number of bulbs in each wattage group.

From equation 5.1, the derived weighted average for the incandescent bulbs is 55 W which is approximated to 60 W. The approximation is essential for consistency with prevalent wattage types in the region.

The efficacy of a lamp is measured in lumens per watt (lm/W). A standard incandescent lamp efficacy is approximately, 15 lm/W; and a good quality CFL bulb and a typical LED can achieve 60 lm/W and 100 lm/W efficacies respectively (Letschert et al., 2013, p. 75). Based on these

standards, the light output or luminous flux (measured in lumens) of a 60 W incandescent light bulb will be 900 lumens. Consequently, a 15 W CFL will also produce an equivalent of 900 lumens and thus, presents an equal and adequate replacement for a 60 W incandescent light bulb. Approximately, 9 W LED will also produce an equivalent of 900 lumens.

The determination of the average annual utilization time (in hours) is an important parameter for calculating the impact of lighting standards. Average daily utilization of 5.1 hours was derived from the survey data. This does not deviate much from the 4.8 hours average daily duration between two power outages per household in Enugu (average duration of power access) derived in the metering report of the Energy Commission of Nigeria (ECN) (ECN, 2013a, p. 133). From the 5.1 hours daily utilization, the total annual utilization time per household is approximately, 1862 hours.

The baseline unit electricity consumption (UEC) in kilowatt-hour (kWh) for lighting is derived from the following equation:

$$UEC_{base} = \frac{\mu h \times (P_{Aw} \times \sum n)}{1000} \quad (5.2)$$

Where:

$UEC_{Base}$	is the baseline unit electricity consumption for lighting in surveyed households (kWh)
$\mu h$	is the mean annual utilization time (hours) for lighting.
$P_{Aw}$	weighted average of the power ratings of the incandescent light bulbs.
$\sum n$	total number of light bulbs to be replaced

The UEC for lighting for the standard promoted efficient lamp ( $UEC_{policy}$ ) is also determined from equation 5.2 by substituting the weighted average of the incandescent light bulbs with the corresponding wattage of the CFL to be used as a replacement.

The annual total final energy savings (TFES) impact from implementing efficient lighting standard is then derived from:

$$TFES = UEC_{base} - UEC_{Policy} \quad (5.3)$$

Emission reduction or carbon dioxide (CO<sub>2</sub>) emission savings (CES) arising from the introduction of lighting standard regulation is determined by applying country data on CO<sub>2</sub> electricity-specific

emission factor (EF)<sup>54</sup> to the estimated TFES according to the following mathematical relationship:

$$CES = TFES \times EF \quad (5.4)$$

The default grid electricity-specific emission factor for Nigeria was applied to determine possible emission reduction from implementing and enforcing lighting regulations. The basic advantage of using the electricity-specific emission factor over the CO<sub>2</sub> emissions per kWh from electricity generation is that the former also take into consideration emissions resulting from transmission and distribution (T&D) losses (Brander, et al., 2011, p. 1). T&D losses account for about 8 to 10 % of electricity generated in Nigeria (ECN, 2013a).

For an aggressive policy scenario, light emitting diodes (LEDs) are presently the highest efficacy lighting technology available.<sup>55</sup> LEDs are not common in the studied area and none of the respondents reported the use of LED lamps. This could probably be due to their very high initial costs.<sup>56</sup> The current Nigerian lighting standard does not cover LEDs. LEDs operate at more than double the energy performance of a CFL and more than ten times the efficiency of an incandescent lamp (U4E policy guide series, 2017a, p. 24). It has been estimated that countries considering a regulation to phase out incandescent bulbs and leapfrog directly to the use of LEDs could save 85 % of consumers' electricity consumption without compromising lighting quality (U4E policy guide series, 2017a, p. 24). The higher efficiency level of LEDs translates into lower energy consumption and greater reductions in CO<sub>2</sub> emissions.

Individual model was built to estimate the policy impact of lighting standard at the national level. This is a stock model that was projected from a regional estimate of incandescent lamps in

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<sup>54</sup>The CO<sub>2</sub> emission factor from fossil fuel combustion reflects the full carbon intensity of the fuel under the assumption of total oxidation of carbon in the fuel during combustion (Brander, et al., 2011).

<sup>55</sup> In comparison with other lighting sources, LED luminous efficacy ranges from 60 – 130 lumens per Watt (lm/W) with a lamp useful lifetime of between 15000 to 30000 hours; CFL luminous efficacy ranges between 50 – 70 lm/W and the lamp operating lifetime is between 6000 to 15000 hours; incandescent bulbs have a luminous efficacy in the range of 8 – 17 lm/W with an operating useful life period of 1000 to 1500 hours (U4E Policy Guide Series, 2017a, p. 20,21,26).

<sup>56</sup> Observed advertised prices for LEDs in Nigeria (Nigerian Naira – NGN): 3W for NGN 700 (US\$2.30); 5W for NGN 850 (US\$ 2.77); 8W for NGN 1,250 (US\$ 4.08) and 15W for NGN 2385 (US\$ 7.78) (LED exhibition by Asteven Group during the Nigeria Alternative Energy Expo, 18-20 October, 2017 in Abuja). Prices are based on the exchange rate of US\$ 1 = NGN 306.5 (Central Bank of Nigeria – CBN official website, 2018).

2014. The stock estimate was adopted from the market analysis study conducted by the United for Efficiency (U4E), a UN Environment initiative (U4E, 2016). The stock is then converted to lighting energy use (kWh) using the derived wattage weighted average and average daily utilization hours. The lighting energy use is then projected forward to 2030 at 3.9 % annual growth rate. The projection is based on the International Energy Agency (IEA) World Energy Outlook projection which estimates that global energy demand for lighting will increase by 50 % from 2014 through 2030 (U4E, 2016, p. 9). Similar to the household level impact estimation, the projection was made as a replacement program for incandescent lamps and considers the current Nigerian MEPS policy for lighting (CFL) in the policy scenario and an aggressive policy scenario targeting the more efficient LEDs.

National emissions impact (avoided CO<sub>2</sub> emissions) was calculated by applying the country-specific CO<sub>2</sub> emission factor.

### **5.3.2 REFRIGERATORS**

Refrigerators provide services by storing food products at specified temperatures, thereby prolonging their life. From the survey conducted, 89 % of the households (representing approximately 263 households) own different types of refrigerators (refrigerator, refrigerator with freezer and freezer alone). This is the current refrigerator saturation level in the households. However, this could be interpreted as saturation of the urban area and may likely not represent the saturation of the entire state. A total of 455 different types of refrigerators were reported in the survey. 81 % (approximately, 369) of these are those with freezers (refrigerator-freezer types), 11 % (approximately, 50 units) are freezer only and 8 % (approximately, 36 units) are refrigerator only (figure 5.9).

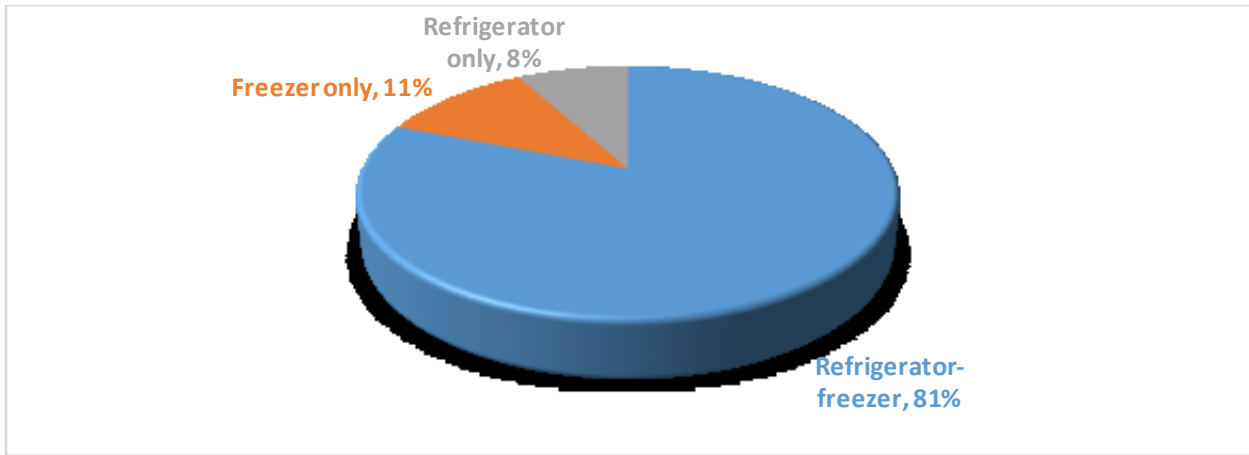


Figure 5.9 Types of refrigerator and freezer units in the surveyed households (Source: Author)

The most popular size of the refrigerator-freezer types in the surveyed households are those in the 200 – 300 litre range (figure 5.10).

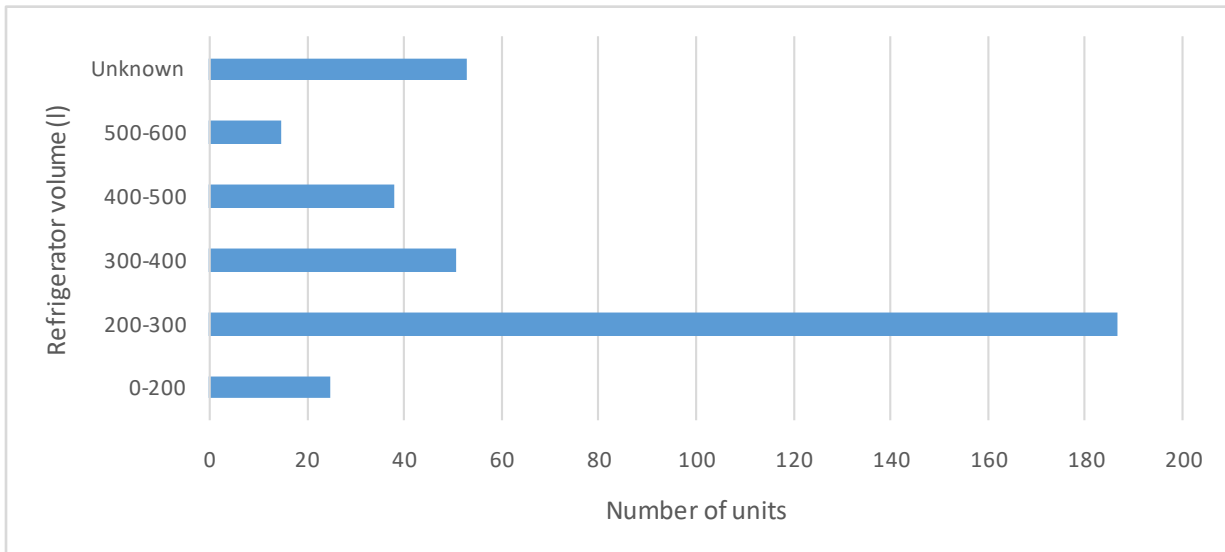


Figure 5.10 Refrigerator-freezer size distributions (Source: Author)

The survey also captured the age range of the refrigerators by asking respondents to provide information on when they bought their refrigerators. The age range is then recorded in three categories: less than 2 years, between 2 and 10 years and older than 10 years. It is expected that older refrigerators will consume more electricity than a new one of a similar size. This could

be attributed to factors such as aging door sealing strips, inefficient compressors, etc.<sup>57</sup> The aging of door sealing strips causes air leakages which reduces the efficiency of the appliance (Cabrera et al., 2015, p. 4). The age category will then give an indication of the energy consumption of the refrigerators and provides an insight on how to design possible refrigerator replacement programs. The age ranges of about 77 % of the most prevalent refrigerator types (refrigerator-freezer) were identified in the sample. This represents approximately 284 refrigerator-freezers. Larger proportion among them approximately, 146 units (approximately, 52 %) are older than 10 years, 39 % (112 units) falls in the 2 to 10 years category and about 9 % (26 units) are relatively new (less than two years of purchase). The distribution of the refrigerator-freezer types by age category is shown in figure 5.11.

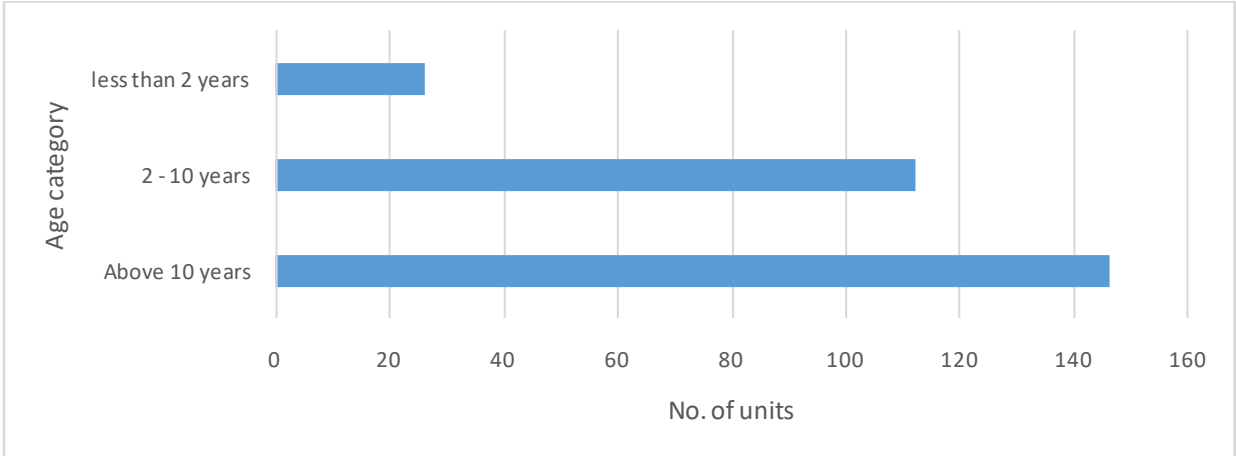


Figure 5.11 Age distribution of refrigerator-freezers (Source: Author)

The purchase status of the refrigerators was also studied. The aim is to have a more in-depth idea of the possible baseline efficiency levels of the existing stock of refrigerators in the visited households. For those households in the survey owning refrigerators, figure 5.12 shows the breakdown of the purchase status of the refrigerators (i.e., whether purchased as brand new or used) when it was bought.

<sup>57</sup> 60 % of heat leakage into the refrigerator come through the walls and doors and refrigerator compressors with more improved efficiency than what was available 10 years ago are available globally (U4E Policy guide series, 2017b, p. 18).

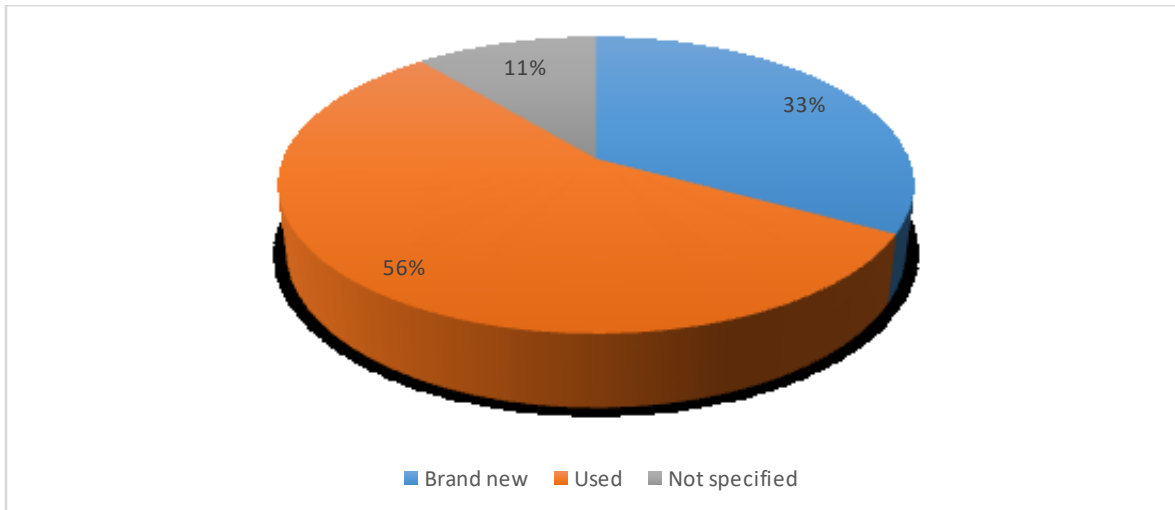


Figure 5.12 Breakdown of the purchase status of refrigerators (Source: Author).

Figure 5.12 shows that more than half (56 %) of the current stock of refrigerators in the surveyed homes were bought as used appliance while 33 % were bought as brand new products. Based on figure 5.11, majority of the existing stock of refrigerators in the survey are aging and these also include products that were purchased as fairly-used. The indication is that most of these products would be of low efficiency levels and will consume more energy.

As illustrated in equation 5.5, the unit energy savings ( $\Delta E$ ) from a refrigerator replacement program is basically, the difference between baseline refrigerator unit energy consumption ( $UEC_{base}$ ) and the unit energy consumption as stipulated by the established refrigerator standard ( $UEC_{policy}$ ):

$$\Delta E = (UEC_{base} - UEC_{Policy}) \quad (5.5)$$

Unit electricity consumption (UEC) of refrigerators varies by type, size (volume), age of the appliance and the appliance regulation that were in effect in that economy when the appliance was sold (U4E Policy guide series, 2017b, p. 14). For the same refrigerator type, each region has a different UEC policy target which is based on available local baseline efficiency data. It is thus necessary to compare refrigerators of similar types and volume. The most prevalent refrigerator types in the survey are those with freezers (refrigerator-freezer). A study by the UN Environment states that the prevalent refrigerator-freezer size in most developing countries

(especially in Sub Saharan Africa) is the 280 L adjusted volume<sup>58</sup> capacity and prior to the implementation of refrigerator standards in major developing economies, a typical combined refrigerator-freezer, with 280 liters adjusted volume capacity consumes 700 kWh annually in homes (U4E Policy Guide Series, 2017b, p. 14). This could be regarded as a plausible estimate of average annual unit energy consumption of refrigerators of similar volume in Nigeria considering their age, the possibility of less than standard maintenance and the absence of regulation. The metering report by the Energy Commission of Nigeria (ECN) estimates that annual electricity consumption of refrigerator-freezer in Nigeria ranges from 100 kWh per year to 2,000 kWh per year (ECN, 2013a, p. 52). However, the ECN estimates did not specify corresponding refrigerator adjusted volumes used for the analysis. A household survey in Ghana showed that refrigerators typically consume 1,200 kWh per year prior to the implementation of refrigerator standards (U4E policy guide series, 2017b, 14).

Due to the high prevalence of refrigerator-freezer types in the studied households, the research calculates energy savings ( $\Delta E$ ) based on this refrigerator types and adopts 280 liter adjusted volume as the standard refrigerator size and 700 kWh as the standard annual baseline consumption.

If the current refrigerator standard in Nigeria is enforced, then the maximum allowed unit energy consumption ( $UEC_{policy}$ ) for refrigerator-freezer type with adjusted volume of 280 liters will be derived from the following equation:

$$UEC_{Policy} = M \times AV + N \quad (5.6)$$

AV is the adjusted volume (in liters) which in this case is 280 liters.

Equation 5.6 expresses a linear relationship between energy consumption of a refrigerator type and the adjusted volume of the product with coefficients M and N as the gradient and y-intercept respectively. In reference to the Standards Organisation of Nigeria (SON), the M and N values for refrigerator-freezer type are 0.777 and 303 respectively (SON, 2013b, p. 6).

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<sup>58</sup> Adjusted volume (AV) is a measure of the refrigerator-freezer volume adjusted to reflect the various operating temperatures of the different refrigerator compartments (Saidur and Masjuki, 2005, p. 59). The AV is an important parameter that is used to determine the general efficiency level used to compare similar products.



Applying equation 5.6, the maximum allowable annual unit energy consumption in kilowatt-hour (kWh) for this category of refrigerator will be:

$$UEC_{Policy} = 0.777 \times 280 + 303 = \mathbf{520.6 kWh}$$

Based on equation 5.5, unit energy savings ( $\Delta E$ ) against the adopted baseline value will be 179.4 kWh per annum amounting to approximately 26 % reduction in unit energy consumption of this type of refrigerators.

The implementation of the current regulatory requirements applicable to residential appliances, no doubt, will promote the supply of more efficient products in the Nigerian market than would have been in the absence of standards. However, considering the current refrigerator MEPS level, there is a limit to realizing significant savings. To realize more energy and emissions savings and reduce efficiency gaps, the more efficient available technologies can also be introduced into the market if regulations stimulate their supply. It is likely that in the absence of more aggressive MEPS levels, further efficiency gains will be slow to achieve which may limit compliance to pledges reached in the Nigeria's NDC. Refrigerator-freezers with 280 liters adjusted volume capacity that consumes 160 kWh per year are already available in the EU market (U4E Policy Guide Series, 2017b, p. 14). Based on this presentation, energy savings from a scenario that assumes the introduction of a more stringent refrigerator regulation was taken into consideration. This scenario assumes the scaling up of the current Nigerian refrigerator standard to stimulate the supply of refrigerators that meet current available technologies in the European market. If the current Nigeria refrigerator MEPS for this refrigerator type and volume is upgraded to reflect refrigerator consumptions of similar types and size in the EU market, unit energy savings against the adopted baseline value would be 540 kWh per annum which represents about 77 % reduction in the unit energy consumption of this refrigerator types.

Statistics from the household survey on refrigerator was then applied to determine the amount of energy that can be saved on annual basis at the household level from replacing the existing older refrigerators (those more than 10 years) both for the policy and the aggressive policy scenarios.

Table 5.2 summarizes the necessary data for performing the calculation.

Table 5.2 Refrigerator parameters

Parameters	Refrigerator statistics
Saturation	89 %
Number of households	295
Baseline average annual energy consumption (UEC <sub>base</sub> ) (kWh/year)	700
UEC <sub>policy</sub> (policy scenario) (kWh/year)	520.6
UEC <sub>policy</sub> (aggressive scenario) (kWh/year)	160
Refrigerator type and volume	Fridge-freezer, 280 litres
Number of fridge-freezers to be replaced	146

The derived UEC<sub>base</sub> and the UEC<sub>policy</sub> were used, in addition to refrigerator stock forecast and other carefully selected assumptions, to model possible national energy and emissions savings till the year 2030. It is assumed that baseline efficiency in the BAU scenario will improve at 1 % (see section 3.3.2), appliance lifetime is 15 years (U4E policy guide series, p. 27; U4E, 2016, p. 2), and it is assumed that refrigerator regulation will be effectively implemented in 2019. In Nigeria, very little appliance sales data exist. This could be because the market is largely import-dependent and mostly unregulated.

The CO<sub>2</sub> emissions reduction or carbon dioxide emission savings (CES) in kgCO<sub>2</sub> impact from refrigerator standard regulation is determined by applying country data on electricity-specific emission factor (EF) to the derived energy savings ( $\Delta E$ ) as defined in the methodology chapter (see equation 3.4).

Over the years, several developed nations have tightened their MEPS levels, thereby stimulating the production of more efficient appliances and realizing more emissions and energy savings. For refrigerators, improved efficiency has been achieved through innovations in refrigerator insulation and the use of more efficient compressors. Table 5.3 shows that the calculated Nigerian MEPS lags behind when compared to the maximum allowable electricity consumption per annum for this typical type and size of appliance (refrigerator-freezer with 280 L adjusted volume capacity) in the various indicated markets.

Table 5.3 Comparison of MEPS levels in different economies for a 280 L fridge-freezer (Source: U4E Policy Guide Series, 2017b, p. 30).

Market	MEPS level (annual energy consumption limits) in kWh/year
EU (2014)	355
Australia (2009)	455
Switzerland (2011)	355
US (2014)	325
China	510
Nigeria (current)	521
Thailand	625

### 5.3.3 ROOM AIR CONDITIONERS

Room air conditioners are units that convey conditioned air without the use of air ducts. Two basic types of room air conditioners are prevalent in the studied households. These are the window-type units and the ductless split systems. From its name, window-type units<sup>59</sup> are designed to be mounted in windows. However, some types are also designed to be mounted through the walls. Wall installation is a more common practice in the case study area. The ductless split systems<sup>60</sup> also known as mini-split systems consist of two separate assemblies; which are the indoor and the outdoor units. The indoor unit is mounted on the wall and connected to the outdoor unit through a refrigerant tube. Both types of room air conditioners have comparatively small cooling capacities in the range of 1450 to 8800 Watts (Constantine, et al., 1999, p 18).

The survey was conducted to determine the saturation rate of room air conditioners, age distribution of the air conditioners and to define the unit energy consumption of the units. 31 % of the analyzed households (representing about 92 households) have air conditioners with a total number of 176 air conditioners reported in the surveyed households. However, due to the random sampling technique adopted in this research, the derived ownership rate may not be

<sup>59</sup> A window-type air conditioner is made up of several components (such as the evaporator, evaporator fan, compressor, condenser, condenser fan, capillary tube and fan motor) all enclosed in one cabinet. The cabinet has both indoor and outdoor segments; the evaporator and evaporator fan constitutes part of the indoor segment while the rest components are part of the outdoor. The fan motor drives both the evaporator and condenser fans.

<sup>60</sup> The indoor unit of the mini-split system contains the evaporator, the evaporator fan and the fan motor. The outdoor unit is made up of the compressor, condenser, condenser fan and the condenser fan motor.

interpreted as the actual air conditioner saturation rate in the state. Figure 5.13 is the distribution of the types of room air conditioners in the visited households. 61 % of the room air conditioners (representing 107.4 air conditioners) are the window-mounted types and 26 % or 45.7 units are the split types.

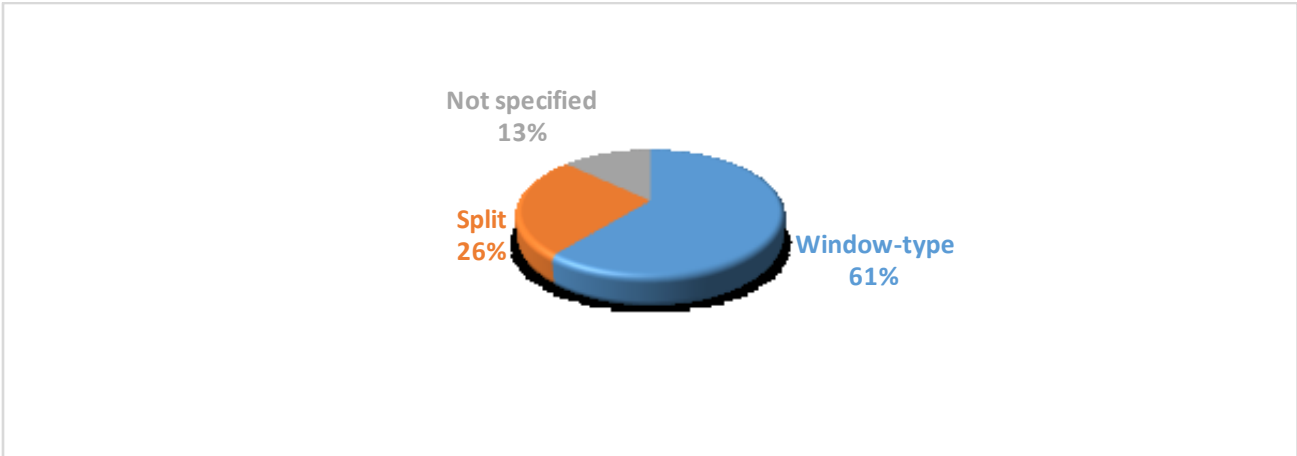


Figure 5.13 Types of air conditioners in visited households (Source: Author)

Respondents were also asked to report the period of purchase of their room air conditioners. For the total indicated room air conditioner types (153.1 of window and split types), the purchase status of 92 % (or 141 units) of the appliances was provided. Similar to the refrigerator analysis, the age distribution of the air conditioners was classified into three major groups; those aged two years and below, those that fall within two to ten years and those older than ten years. 26 of the units (18.4 %) are of the age two years and below, 47 units (33.3%) are more than 10 years and 68 units (48.2 %) fall within the age bracket of two to ten years (figure 5.14). Due to the absence of regulations, it is expected that older room air conditioners will be of poor efficiency levels and thus, consume more electricity. The age category will then give an indication of the energy consumption of the room air conditioners and provide an insight on how to design possible room air conditioner replacement programs.

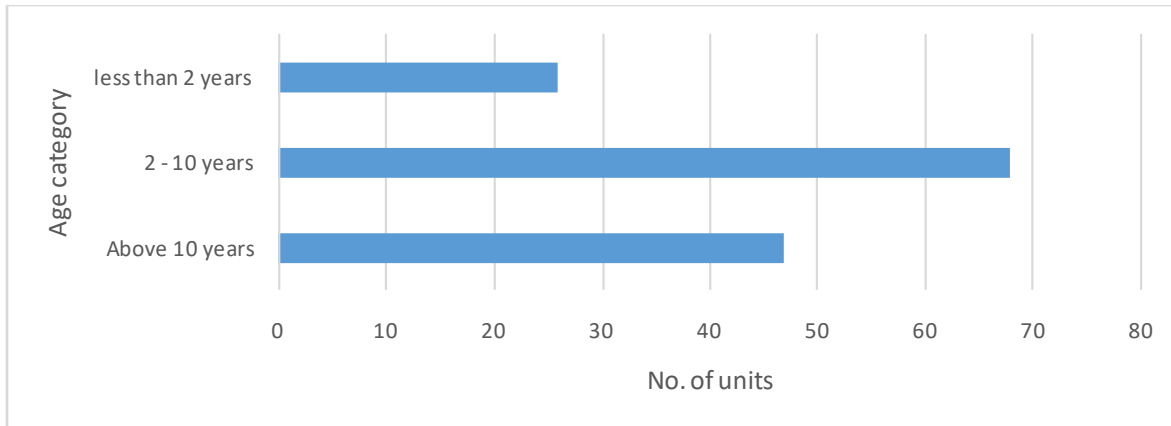


Figure 5.14 Age distribution of room air conditioners (Source: Author)

The derived average daily hours of power access (5.1 hours) was used as a proxy to represent daily hours of appliance usage. This was used to determine the yearly average utilization time of 1862<sup>61</sup> hours per annum (h/a).

Due to the difficulty in locating and accessing the nameplate information, especially for mounted air conditioners, it was relatively challenging to report the cooling capacities of the air conditioning units. However, a study by Letschert and McNeil (2012, p. 8) has shown that the most prevalent room air conditioners in the ECOWAS countries are those with a cooling capacity of 3.5 kilowatts (kW) with a predominant baseline energy efficiency ratio (EER)<sup>62</sup> of 2.7. The metering report of the Energy Commission of Nigeria (ECN) indicates that annual household electricity consumption of air conditioners ranges from 0 kWh/year to 3400 kWh/year (ECN, 2013a, p. 42). The ECN report does not indicate corresponding cooling capacities or EERs of the air conditioners used in the analysis. It is assumed that the large gap in the ECN reported values could be as a result of varying air conditioner cooling capacities that must have been assessed in the survey. The current Nigerian MEPS for air conditioners covers all air conditioning systems with cooling capacity up to 20 kW (SON, 2013a, p. 7). The MEPS evaluates air conditioner efficiency based on their EER and stipulates that air conditioners must meet a minimum EER value of 2.8 before they can be allowed into the country (SON, 2013a, p. 7). High energy-efficient split type room air conditioners with EER of 5.0 are already commercially available in

<sup>61</sup> The yearly utilization hours of 1862 is based on 8760 hours in a year.

<sup>62</sup> The EER is the ratio of the appliance cooling capacity in Watt (W) to the input Power (W) required for cooling measured at fixed outside ambient temperature of 35°C, inside temperature of 27°C and at 50 % humidity level (SON, 2013a, p. 7).

the EU and China (Letschert et al., 2013, p. 74). However, based on expert’s advice and general availability, the research will adopt 4.0 EER as best available technology (BAT).

The UEC of air conditioner is derived by multiplying the cooling capacity (in kW) of the product by the annual utilization time in hours (h) and dividing by the product’s EER value as expressed in equation 5.7:

$$UEC = \frac{\text{Cooling capacity} \times h}{EER} \quad (5.7)$$

Table 5.4 summarizes the information for modeling household and national level impacts of implementing room air conditioner efficiency standard. The assessment is based on a replacement program for old room air conditioners (preferably, those older than 10 years which are considered to be less efficient).

Table 5.4 Room air conditioner parameters

Parameters	Room air conditioner statistics
Households	295
Saturation	31%
Number of units to be replaced	47
EER baseline	2.7
EER Policy	2.8
EER APS	4.0
Cooling capacity	3.5
Utilization time in hours (h)	1862
Calculated baseline (BAU) UEC (kWh/year)	2414
Calculated current MEPS levels UEC (kWh/year)	2328
Calculated UEC (kWh/year) for APS	1629

The current household saturation level is derived from the survey data. Baseline EER value is based on published estimates of baseline technology efficiency of room air conditioners with a cooling capacity of 3.5 kW in the ECOWAS countries (Letschert and McNeil, 2012, p. 8). EER for the policy scenario is based on the minimum requirement of the current Nigerian air

conditioner standard. EER for the aggressive policy scenario is guided by the efficiency level of the already commercially available room air conditioners with similar cooling capacity in the EU and China markets (Letschert et al., 2013, p. 74). The values were input in equation 5.7 to calculate the UEC for the different scenarios. Stock forecast is generated by the model which is developed using 2015 stock data of room air conditioners in Nigeria with a cooling capacity of 3.5 kW (U4E, 2016). Based on a 5 % economic growth rate, the air conditioner stock increases at an average of 2.8 % from 2015 through 2030. Very little air conditioner market data exists in Nigeria. This can be attributed to limited local manufacturing capacity which means that most of the products are imported. The market is also quite unregulated with numerous brand names which are imported from different countries depending on importer's choice and capacity.

## 5.4 RESULTS AND DISCUSSION

The results obtained from modeling the policy impacts of appliance regulations as performed in the previous section are presented below.

### 5.4.1 REFRIGERATOR

Based on the refrigerator statistics and methodological process offered in the previous section, the household level impacts of the refrigerator regulation on energy consumption and carbon dioxide emission both at the policy and aggressive policy scenarios are summarized in table 5.5. The emission reduction was obtained by applying electricity-specific emission factor of 0.43963136 kgCO<sub>2</sub>/kWh for Nigeria (Brander, et al., 2011, p. 6) to the derived energy savings.

Table 5.5 Refrigerator household level policy impacts

	<b>BAU scenario</b>	<b>Policy scenario</b>	<b>Aggressive policy scenario</b>
Household energy consumption (MWh)	102.5	76.2	23.4
Household energy savings (MWh)	–	26.3	79.1
% electricity consumption reduction Vs BAU		26 %	77 %
CO <sub>2</sub> emissions (kgCO <sub>2</sub> )	45,053.4	33,507	10,298
CO <sub>2</sub> emission savings (kgCO <sub>2</sub> )	–	11,546.4	34,755.4

From table 5.5, approximately 26.3 MWh of electricity and 11,546.4 kgCO<sub>2</sub> emissions will be reduced annually if the current refrigerator standard is effectively implemented as opposed to what would have been in the absence of regulation. Savings are as a result of the reduction in appliance energy consumption due to the replacement of the identified old existing stock with products that meet current MEPS. These savings may likely be underestimated since the majority of the older refrigerator models in the existing stock will consume more than 700 kWh per year. According to the United States Environmental Protection Agency (EPA) online GHG equivalent calculator,<sup>63</sup> the derived emission reduction is equivalent to removing 2.5 passenger vehicle cars from the streets of Enugu for one year. The calculated emission reduction does not account for the release of fluorinated gases used as refrigerants in old refrigerators which are released into the environment during use, repair or when the refrigerator is disposed at the end of its useful life period.<sup>64</sup>

Table 5.5 also indicates that, if the current EU standards are enforced and assuming that the typical unit is a refrigerator-freezer type with 280 L capacity, energy savings against the baseline model would be 79.1 MWh for the modeled households. Emissions reduction against this aggressive policy background will amount to 34,755.4 kgCO<sub>2</sub> annually which is equivalent to emissions from 7.4 passenger vehicles driven for one year. Considering the ECN reported average yearly electricity consumption of 3330 kWh for Enugu, the derived electricity savings in the policy and aggressive policy scenarios can provide electricity for approximately, 8 and 24 homes respectively. In reference to the derived refrigerator saturation level in the survey (which indicates that refrigerator stock in households is approaching market saturation), it could be interpreted that the majority of refrigerator purchases will be for replacement of the existing stock in households rather than first time purchases. This underscores the need to design appropriate refrigerator replacement programs. With refrigerator operational lifetime of 15 years, replacement programs targeting refrigerators older than 10 years would provide households with the opportunity to turn in their old and inefficient products (which consume

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<sup>63</sup> The US EPA GHG equivalent calculator estimates that a passenger vehicle emits an average of 4.63 metric tons CO<sub>2</sub>e per vehicle per year. The derived emissions reduction is also equivalent to GHG emissions from 28,651 miles (about 46,109 km) driven by an average passenger vehicle. Source available online at: <https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator> (Last accessed on: 2 June, 2018).

<sup>64</sup> Many old refrigerators contain high GWP fluorinated gases which add to the total global warming related impact of any refrigerating equipment (U4E policy guide series, 2017b, p. 63). However, the introduction of MEPS will help regulate refrigerant gases used in refrigerators.



more energy) and to replace them with more efficient types. However, the management of gases after such replacement programs to ensure their safe disposal requires careful policy attention.

Based on survey statistics and the assumptions enumerated in section 3.3.2, the PAMS spreadsheet model was used to estimate national impact of refrigerator regulation (figure 5.15).

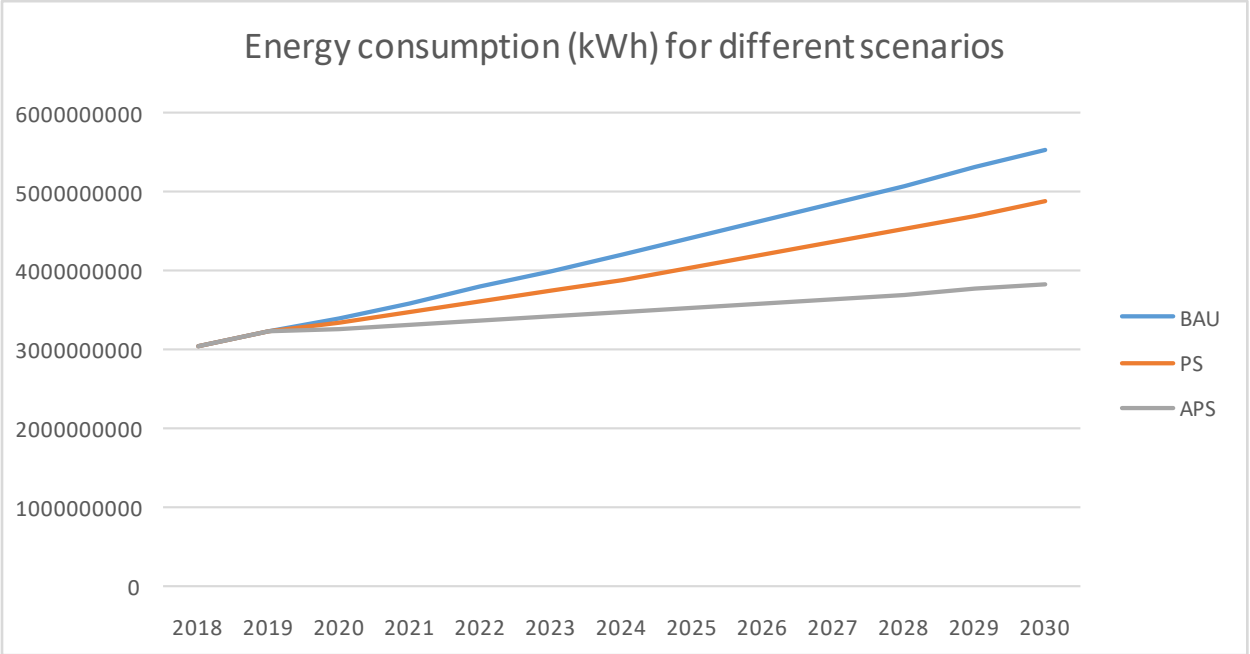


Figure 5.15 Energy consumption (kWh) for different scenarios - refrigerator (Source: Author)

From figure 5.15, electricity consumption of refrigerator-freezers of 280 L size in households will reach approximately 5.5 billion kWh (5.5 TWh) in 2030 under the BAU scenario. Energy use is the energy of all fridges sold after the assumed implementation year of 2019. Each year, more refrigerators are sold and those sold in the first year remain in the stock, as a result, overall energy use keeps increasing cumulatively. In reference to the model projections, from a refrigerator stock data of 4,051,484 in 2018 and based on assumptions of economic parameters, refrigerator stock will grow by 5.7 % annually between 2019 and 2030 bringing the total stock to 8,281,050 in 2030. If standards are not quickly implemented and effectively enforced, all of those units could be of poor efficiency levels and it would be years before end-users would economically replace them with more modern and efficient types, which undermine

government's efforts to achieve established national targets. In the efficiency policy scenarios, energy is also growing, but overall, at a considerably lower rate because each refrigerator sold after 2019 is assumed to meet established standards and would be more efficient than would have been the case in the absence of the policy. In reference to table 5.6, implementing current refrigerator standards would reduce refrigerator energy consumption by 11 % in 2030 compared to BAU. Likewise, scaling up of the current MEPS to reflect refrigerator technology efficiency levels that are already commercially available in the European market, will further reduce refrigerator energy consumption by 31 % in 2030 compared to BAU consumptions in 2030. The accrued saving is the difference in energy consumptions between the BAU and policy scenarios.

Emission reductions are calculated by multiplying annual electricity savings in each year by the CO<sub>2</sub> emission factor of 0.43963136 kgCO<sub>2</sub>/kWh. The key assumption here is that energy source for future electricity generation will continue to significantly come from natural gas based thermal fired power plants. Based on this assumption, the effective implementation of refrigerator standards will yield CO<sub>2</sub> emissions savings of 0.3 million tons (Mt) CO<sub>2</sub> and 0.7 MtCO<sub>2</sub> in 2030 in the policy and aggressive policy scenarios respectively compared to the BAU emissions level.<sup>65</sup> The estimated emission reduction in the aggressive policy scenario is equivalent to removing 160,965 passenger cars from Nigerian roads for one year. Table 5.6 summarizes the potential national impacts of the implementation of refrigerator regulation.

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<sup>65</sup> The BAU emission in 2030 was estimated at 2,434,585,630 kgCO<sub>2</sub> or 2.4 MtCO<sub>2</sub> (Source: Author).

Table 5.6 Refrigerator national policy impacts

	BAU		Policy scenario		Aggressive policy scenario	
	2025	2030	2025	2030	2025	2030
Energy consumption (TWh)	4.4	5.5	4.0	4.9	3.5	3.8
Energy savings (TWh)	-	-	0.4	0.6	0.9	1.7
% reduction VS BAU			9.1 %	11 %	21 %	31 %
Emissions (MtCO <sub>2</sub> )*	1.9	2.4	1.8	2.1	1.6	1.7
Emissions savings (MtCO <sub>2</sub> )	-	-	0.1	0.3	0.3	0.7
% contribution to national emissions reduction target				0.17 %		0.40 %

\*MtCO<sub>2</sub> is million tons CO<sub>2</sub>

#### 5.4.2 ROOM AIR CONDITIONERS

Table 5.7 presents the annual household level impacts of room air conditioner regulations in the surveyed households. Based on the calculation methods presented in section 5.3.3, it shows energy consumption in the three conceptualized scenarios and highlights estimated energy and emissions savings.

Table 5.7 Room air conditioner household level policy impacts

	<b>BAU scenario</b>	<b>Policy scenario</b>	<b>Aggressive policy scenario</b>
Household energy consumption (MWh)	114	109.4	77
Household energy savings (MWh)	–	4.6	37
% electricity consumption reduction Vs BAU		4 %	32.5 %
CO <sub>2</sub> emissions (kgCO <sub>2</sub> )	49,880	48,103	33,660
CO <sub>2</sub> emission savings (kgCO <sub>2</sub> )	–	1777	16,220

The result indicates that the replacement of the existing old stock of air conditioners in the surveyed households with products that meets current MEPS would reduce annual electricity consumption of room air conditioners by 4 % compared to the baseline case. However, the implementation of MEPS targeting technically achievable best available efficiency levels can reduce annual electricity consumption of air conditioners by 33 % compared to BAU scenario. As a result, annual CO<sub>2</sub> emissions would be reduced by 1777 kgCO<sub>2</sub> and 16,220 kgCO<sub>2</sub> in the policy and aggressive policy scenarios respectively. Air conditioner standards set at a more stringent level, therefore, represents a nine-fold increase in annual CO<sub>2</sub> emissions savings of this category of room air conditioners when compared to estimated emissions reductions from the current standards.

To put the result into context, the capacity of the estimated energy savings in stabilizing or reducing current electricity supply-demand gap that exists in the case study area was evaluated. In this background, total annual electricity savings from replacing old room air conditioners with room air conditioners meeting the current air conditioner standards, would be enough to provide electricity for 1.4 households. Likewise, leapfrogging into a more stringent air conditioner standard will result in electricity savings that would be enough to power approximately eleven households.

For the national level impacts, table 5.8 presents national energy savings in 2025 and 2030 achievable from the implementation of air conditioner regulations. The calculation presented in

table 5.8 is deduced from figure 5.16 which is the result of the modeling and the assumptions described in chapter 3.

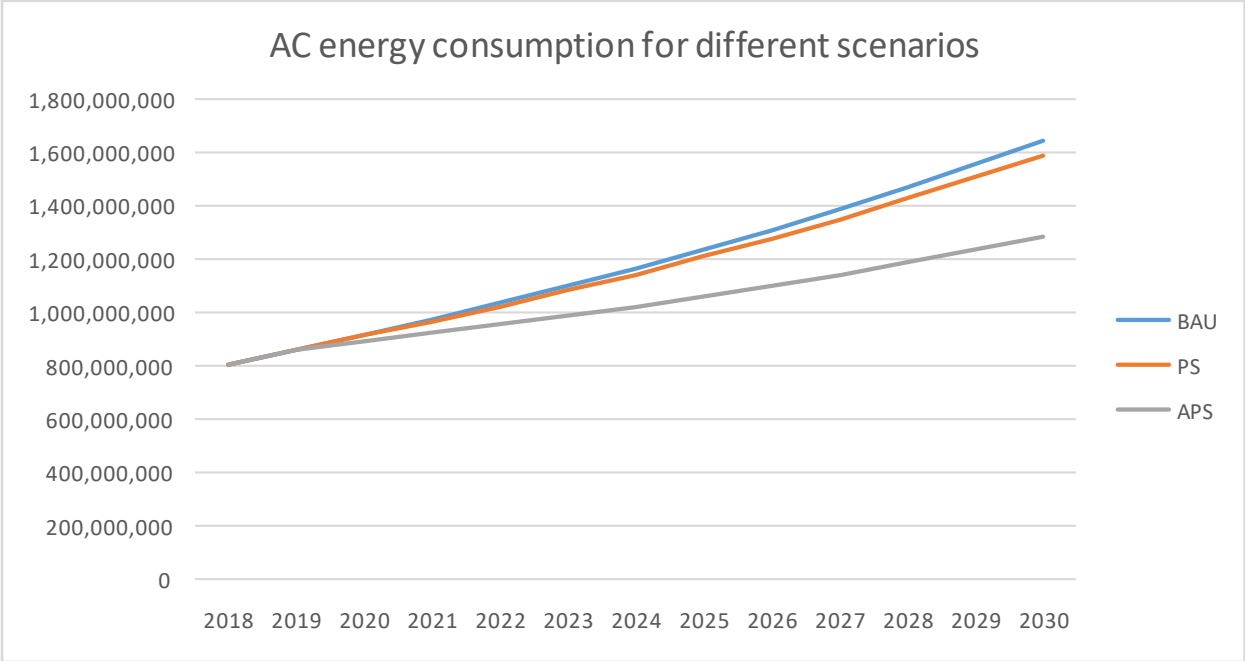


Figure 5.16 Energy consumption (kWh) for different scenarios – room air conditioners (Source: Author)

In reference to the model projections; from the room air conditioner stock data of 380,251 in 2018 and based on assumptions on economic parameters, room air conditioner stock will grow by 2.8% annually between 2019 and 2030 bringing the total stock to 692,531 in 2030.

Table 5.8 Air conditioner national policy impacts

	BAU		Policy scenario		Aggressive policy scenario	
	2025	2030	2025	2030	2025	2030
Energy consumption (TWh)	1.24	1.64	1.21	1.59	1.05	1.28
Energy savings (TWh)	-	-	0.03	0.05	0.19	0.36
% reduction VS BAU			2.4 %	3.1 %	15.3 %	22 %
Emissions (MtCO <sub>2</sub> )*	0.54	0.72	0.53	0.70	0.50	0.60
Emissions savings (MtCO <sub>2</sub> )	-	-	0.01	0.02	0.04	0.12
% contribution to national emissions reduction target				0.01 %		0.07 %

\*MtCO<sub>2</sub> is million tons CO<sub>2</sub>

From the graph (figure 5.16), it could be interpreted that the present air conditioner standards, just like that of the refrigerator, may not be quite ambitious resulting in significant efficiency gaps. There is only 3.1 % electricity consumption reduction impact in 2030 by institutionalizing the current air conditioner MEPS in Nigeria. With a 22 % energy savings potential, the adoption of the already commercialized, more efficient air conditioner technologies, has much greater impact than current policies by the year 2030. Table 5.9 compares the current developed Nigerian MEPS for air conditioners with baseline energy efficiency of room air conditioners between 2010 and 2011 in China, Korea, India, South Africa and the EU, where majority of the products are imported from. Higher MEPS value means higher efficiency level.

Table 5.9 Comparison of MEPS levels in different economies for room air conditioners in 2010-2011 (Source: Letschert, et al., 2013, p. 74; Shah, et al., 2012, p. 50).

<b>Market</b>	<b>MEPS level (EER Watt/Watt)</b>
EU	3.2
China	3.2
Japan	4.1
Korea	3.8
India	2.8
South Africa	2.9
Nigeria (current)	2.8

Considering baseline air conditioner efficiency levels obtainable in the economies listed in table 5.9 in 2010 – 2011, it could be concluded that current Nigeria’s air conditioner MEPS level is not quite ambitious, which may attract the dumping of products with poor efficiency levels into the Nigerian market and undermine achieving the technical energy savings potential that exists.

### **5.4.3 LIGHTING**

In reference to the lighting statistics and methodological approach presented in section 5.3.1, annual UEC for lighting in the three scenarios is presented in table 5.10.

Table 5.10 Definition of UEC for lighting and corresponding CO<sub>2</sub> emissions.

<b>Scenarios</b>	<b>UEC (MWh)</b>	<b>CO<sub>2</sub> emissions (kgCO<sub>2</sub>)</b>
Baseline	148	65,013
Policy	38	16,549
Aggressive policy	22	9456.4

The annual total final energy savings (TFES) and CO<sub>2</sub> emissions reduction impacts from the adoption of CFL lighting technology and the implementation of a more stringent lighting standard (LED) at the household level are illustrated in table 5.11. The CO<sub>2</sub> emission reduction impact was obtained by applying electricity-specific emission factor of 0.43963136 kgCO<sub>2</sub>/kWh for Nigeria (Brander, et al., 2011, p. 6) to the derived energy savings.

Table 5.11 Lighting household level policy impacts

	Annual savings	
	Policy scenario (CFL)	Aggressive policy scenario (LED)
Household electricity savings (MWh)	110	126
CO <sub>2</sub> emissions savings (kgCO <sub>2</sub> )	48,464	55,556

From table 5.11, the calculated annual CO<sub>2</sub> emissions savings in the policy and aggressive policy scenarios is equivalent to the total CO<sub>2</sub> emissions from 10.4 and 11.9 passenger vehicles respectively that is driven for one year. Considering the ECN reported average yearly electricity consumption of 3330 kWh per household in Enugu, the calculated household electricity savings in the policy scenario can provide electricity for 33.1 homes. Likewise, electricity savings impact from implementing policies targeting LEDs can be used to provide electricity for approximately 38 homes.

The projected BAU energy consumption for lighting and national level impacts of implementing lighting standards is depicted in figure 5.17 and Table 5.12 summarizes the estimated savings from the lighting standard regulation. From an incandescent lighting stock data of 19,748,000 in 2014 (U4E, 2016) and based on IEA's projections, it is derived that lighting stock will grow by 3.9 % annually between 2019 and 2030 bringing the total stock of incandescent lamps to 36,422,680 in 2030.



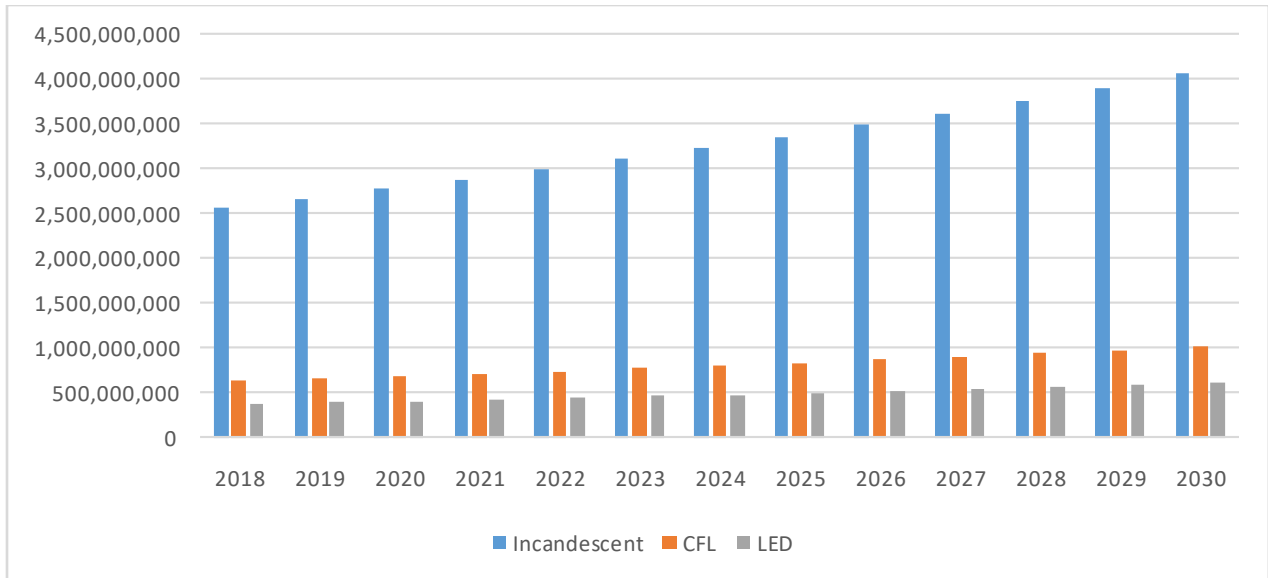


Figure 5.17 Energy consumption (kWh) for different scenarios – lighting (Source: Author)

Table 5.12 Lighting national policy impacts

	BAU		Policy scenario		Aggressive policy scenario	
	2025	2030	2025	2030	2025	2030
Energy consumption (TWh)	3.4	4.1	0.8	1.0	0.5	0.6
Energy savings (TWh)	-	-	2.5	3.1	2.9	3.5
% reduction VS BAU			74 %	76 %	85 %	85 %
Emissions (MtCO <sub>2</sub> )*	1.5	1.8	0.4	0.5	0.2	0.3
Emissions savings (MtCO <sub>2</sub> )	-	-	1.11	1.34	1.26	1.52
% contribution to national emissions reduction target			0.6 %	0.8 %	0.7 %	0.9 %

\* Million tons CO<sub>2</sub>

Note: numbers may not add up due to approximation

Figure 5.17 shows that estimated future benefits of policies to support lighting market transformation increases linearly starting from 2019 as the inefficient incandescent lamps are replaced by more efficient CFLs at an average rate of approximately 1,042,168 units per year. The switch to CFLs will provide a 74 % improvement over the baseline case or electricity savings of approximately, 2.5 terawatt hour (TWh) by 2025 and 3.1 TWh (76 % savings) by 2030. However, policies mandating the implementation of a more stringent lighting standard (LEDs) can reduce final energy consumption of lighting by 85 % compared to BAU with electricity savings of 2.9 TWh in 2025 and 3.5 TWh in 2030. Lighting standard set at a more aggressive level presents about 12 % additional energy savings compared to estimated savings potential from current standard. Given the short lifetime of incandescent bulbs, the policy impact of effectively implementing regulations that mandate the use of energy-efficient lamps is immediate (figure 5.16).

Table 5.12 also illustrates the estimated CO<sub>2</sub> emissions reductions from a lighting efficiency market transformation program. Institutionalizing CFL standards would reduce annual CO<sub>2</sub> emissions from the use of incandescent lamps by 73 % in 2025 with emissions savings of approximately 1.11 million tons (Mt) CO<sub>2</sub> in 2025 and 1.34 MtCO<sub>2</sub> in 2030. Likewise, leapfrogging to a more efficient LED will reduce emissions from the use of incandescent lamps by 84 % in 2025 with corresponding emissions savings of 1.26 MtCO<sub>2</sub> in 2025 and 1.52 MtCO<sub>2</sub> in 2030.

## **5.5 CHAPTER CONCLUSION**

In this chapter, the household-level and national-level impacts of the implementation of appliance standards (MEPS) were examined. The assessment is informed by recently collected data in the case study regarding the energy use of products that were studied and data from reliable secondary sources.

The current sets of MEPS modeled in this research would achieve annual energy savings of 141.1 MWh in the surveyed households. Considering the calculated total BAU consumption of approximately, 365 MWh for the modeled products, the estimated savings represents a 39 % reduction in annual residential electricity demand. Leapfrogging to a more stringent standard for the modeled products would yield total annual household energy savings of approximately, 243 MWh or 67 % reduction in residential electricity demand. Considering the current

regulations, lighting presents the biggest savings potential out of all the products assessed. The switch to CFL provides approximately 78 % of the estimated total energy savings. Replacing old room air conditioners with those meeting current air conditioner standards contributes only about 3 % of the calculated total energy savings and replacing old refrigerator-freezers with units that meet current standards contribute about 19 % of the derived total energy savings. The huge energy savings potential from lighting standards could be attributed to the predominant use of incandescent lamps for lighting as reported in the survey. Even though air conditioners contribute the lowest savings potential amongst the covered products, their high per unit energy usage (baseline estimates of 2414 kWh/year) makes room for huge energy efficiency improvement for this appliance. Under the assumption that the current standards are made more stringent, there are more improvements in the energy savings potentials of refrigerators and air conditioners than light bulbs. Air conditioner standards that are set at a more aggressive level represents about 8-folds increase in annual energy savings when compared to estimated energy savings from the current standards. Refrigerator improvement is at a level of 3-folds while a more stringent lighting standard only represents a one-fold improvement from current lighting standards. Thus, this also underscores the fact that the current MEPS for refrigerator and air conditioners are probably not very ambitious. Market transformation approach that will consider a review of the current appliance standards to more stringent levels may give more priority to air conditioners and refrigerators. To put the results into context, savings estimates were evaluated based on the capacity to mitigate existing electricity supply-demand gap in the case study area. As a result, taking into the cognizance the estimated average annual electricity consumption of 3330 kWh per household in Enugu (ECN, 2013a, p. 133), the total energy savings from the assessed products can provide electricity for 42.4 and 73 households in the policy and aggressive policy scenarios respectively.

The annual total avoided CO<sub>2</sub> emission from the current standard for the covered products is 61,787.4kgCO<sub>2</sub>. Compared to BAU CO<sub>2</sub> emissions estimates of 159,946.4 kgCO<sub>2</sub>, this represents approximately, 39 % emissions reductions potential in the surveyed households. Scaling up current standards to meet the best commercially available efficiency levels for covered products would reduce annual CO<sub>2</sub> emissions by 106,531.4 kgCO<sub>2</sub>. When compared to the estimated BAU CO<sub>2</sub> emissions, this amounts to approximately, 67 % emissions mitigation potential for the

households. As expected, lighting presents the greatest CO<sub>2</sub> emissions reductions potential contributing almost 78 % (48,464 kgCO<sub>2</sub>) of the total estimated CO<sub>2</sub> emissions savings in respect to current standards. This could be attributed to its corresponding highest energy savings potential. Refrigerators and air conditioners contribute approximately, 19 % (11,546.4 kgCO<sub>2</sub>) and 3 % (1777 kgCO<sub>2</sub>) emissions reductions respectively. Major improvement in emissions savings potential of the covered products is noticed more for air conditioners and refrigerators in the aggressive policy scenario. When standards are made more stringent, emissions reductions of refrigerators and air conditioners improved to 33 % (34,755.4 kgCO<sub>2</sub>) and 15 % (16,220 kgCO<sub>2</sub>) respectively of the total estimated emissions savings potential of 106,531.4 kgCO<sub>2</sub> from more aggressive standards of the assessed products. Under this scenario, emissions savings potential from lighting reduces from 78 % to 52 % or 55,556 kgCO<sub>2</sub>.

National level impacts show that the implementation of the current MEPS can reduce final energy consumption of the modeled products by 34.4 TWh or 32 % between 2019 and 2030 compared to BAU cumulative consumption of 106.71 TWh for all covered products. Implementation of MEPS policies targeting technically achievable best available efficiencies for these products can further reduce the final energy consumption of these products by approximately, 46 TWh or 43 % compared to the cumulative BAU estimated consumption for all covered products (see figure 5.15). Similar to household level impacts, lighting presents the highest savings opportunity. Considering current policies, lighting would contribute 87 % (30 TWh) of the total savings opportunity while refrigerators and room air conditioners would contribute 12 % (4.1 TWh) and 0.9 % (0.3 TWh) respectively. In a more aggressive policy consideration, lighting contributions to total savings is 74 % (or 34 TWh) while energy savings from refrigerators and room air conditioners represent 22 % (10 TWh) and 4.4 % (2 TWh) respectively of the total estimated energy savings.

Considering current products' standards, appliance-related CO<sub>2</sub> emissions would be reduced cumulatively by 15.14 MtCO<sub>2</sub> or by 32 % between 2019 and 2030 when compared to total BAU emissions of 46.94 MtCO<sub>2</sub> within this period. In a more aggressive policy scenario, emissions reductions improved further to 20.29 MtCO<sub>2</sub> (or 43 %) within the same period compared to BAU emissions estimate. As expected, in the current policy scenario, lighting presents the highest CO<sub>2</sub> emissions mitigation potential of 86 % (13.2 MtCO<sub>2</sub>) of the estimated cumulative BAU

emissions for the modeled products. Refrigerator contributes approximately, 12 % (or 1.81 MtCO<sub>2</sub>) while room air conditioners contribution amounts to 0.8 % (or 0.13 MtCO<sub>2</sub>) reductions. However, similar to the household level impacts, the research finds out that refrigerator-freezers and room air conditioners would present more per unit emissions reduction improvements with the introduction of more stringent policies. This could be attributed to the high per unit energy consumption of these two appliances when compared to light bulbs. Based on the estimated impacts, it could be said that scaling up the current standards (especially for refrigerator and air conditioner) would present good opportunities in maximizing energy and emissions savings in households.

Considering national target of achieving 179 MtCO<sub>2</sub> greenhouse gas (GHG) emissions reduction through the improvement of economy-wide energy efficiency, as detailed in Nigeria’s NDC, the enforcement of the current MEPS for the covered products would contribute about 8.5 % of the estimated national emissions reduction target while reviewing the current policies to a more stringent levels would cover about 11.3 % of the national emissions reduction targets by 2030. Figure 5.18 is the comparison of the energy consumption (kWh) in the different projection scenarios for the covered products in this assessment.

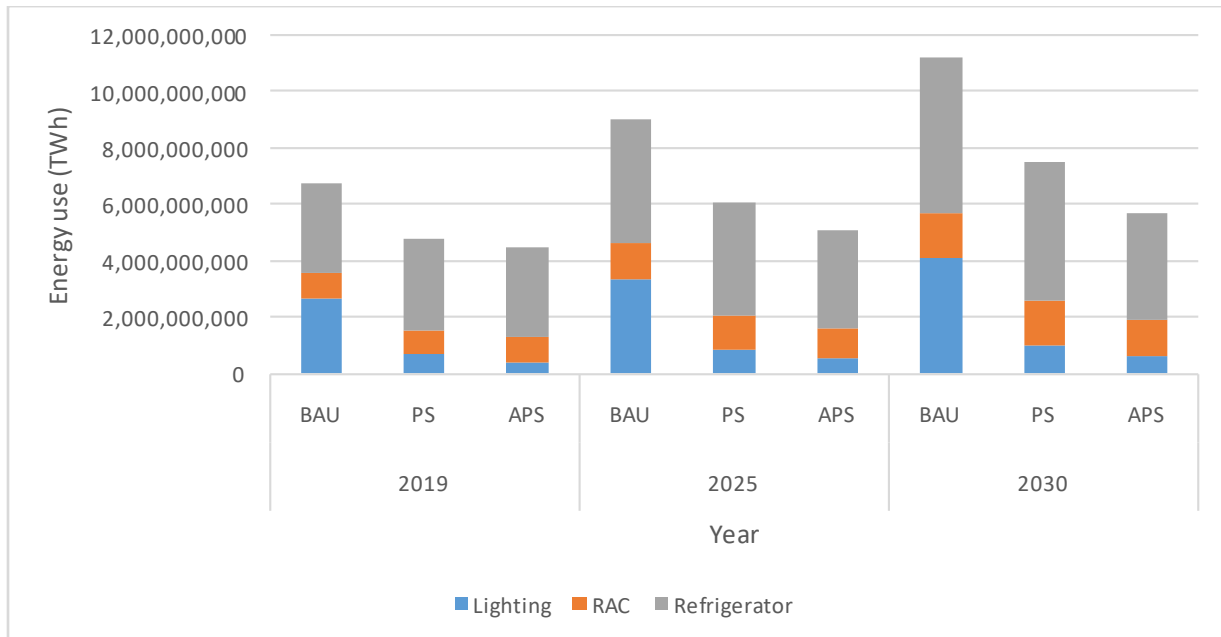


Figure 5.18 End use comparisons of projection scenarios for the covered products

The assessment performed in this research is limited to commercially available technologies. The identification of BAT was guided by evaluation studies found in the literature (Letschert et al., 2013; U4E policy guide series 2017a, U4E policy guide series, 2017b). The major criteria in choosing BAT ensures that all efficiency standard levels that were considered are commercially deployable technologies. Nevertheless, it should be mentioned that it is also certainly possible that technologies that are not commercially available today may become mass-producible in just a few years from now. Consequently, considering the uncertainty of future technology innovations, the aggressive policy results could be interpreted as conservative (in terms of maximum achievable technical potential).

### **5.5.1 DISCUSSION OF UNCERTAINTIES**

Due to the lack of certain national data and the challenges of forecasting events in the future with a high level of accuracy, the estimates presented in this research are subject to a certain level of uncertainty. The most considerable sources of uncertainties are the forecast parameters and data driven variables.

Forecast parameters: this type of uncertainty is associated with models projecting into the future because events in the future cannot be accurately predicted. Data that constitutes main drivers to appliance diffusion forecast in this research, especially economic development parameters (GDP growth rates and GDP per capita) are possible sources of uncertainties because of their influence on appliance stock growth rates. To reduce the impact of uncertainties from this data set, economic development parameters were carefully selected from reliable sources and compared with national published values. It is reported that the impact of these types of uncertainties on the final result could range from moderate to significant (Letschert, et al., 2013, p. 80).

Data driven variables: these could also present a level of uncertainty in analysis involving forecasting future events. Data driven variables considered sensitive in this case are the stock input estimate, baseline efficiency distribution, population estimate and utilization hours. Stock input estimates and baseline efficiency distributions in this research were obtained from reliable sources. Current population and population forecast estimates were derived from the World Bank and national population commission in Nigeria. However, these variables (stock, baseline efficiency and population) are based on historical trends which are observed real

values. Utilization hours are based on average values from the household survey. As a result, these parameters are considered as sufficient data. It is reported that, depending on the reliability of data, impacts from data driven variables on results are mostly small to moderate (Letschert et al., 2013, p. 80).

## **6. REVIEW OF THE INSTITUTIONAL MANDATES AND GOVERNANCE OF KEY MDAs IN THE APPLIANCE ENERGY EFFICIENCY SUB-SECTOR.**

### **6.1 INTRODUCTION TO CHAPTER SIX**

This chapter presents a critical analysis of the activities of government institutions and agencies that play active roles in the appliance energy efficiency sub-sector. It is meant to address objectives three and five of this research. The result presented here is derived from the reviews of the National Energy Efficiency Action Plan (NEEAP) and the statutory mandates of key institutions and also from the analysis of data from conducted semi-structured interviews and questionnaire responses from key informants in the contacted ministries, departments and agencies (MDAs). A review of the relevant acts and laws upon which these institutions were established and their assigned roles as stipulated in the NEEAP was performed to have background knowledge of their respective activities in championing appliance energy efficiency in Nigeria. The analysis is dedicated mainly to identifying and highlighting possible areas of conflicts and overlaps in activities and mandates of the respective institutions. It will also reveal areas of weak institutional involvement in advancing the MEPS program in Nigeria.

The mandates of the institutions were extensively reviewed and the relevant institutions were selected based on their roles and activities in championing end-use energy efficiency with consideration to the following policy areas: development of the NEEAP, setting and implementation of MEPS; specified functions in the area of monitoring, verification and enforcement of established appliance standards, advisory and support roles for MEPS. The selected institutions (as enumerated in section 3.2.1) were contacted through a snowball sampling method. Interviews were scheduled and conducted with these institutions to gain expert views and clarifications on the reviewed mandates and roles. In respect to the above enumerated policy areas, the information gathered from the review of the NEEAP revealed major ongoing or planned activities in advancing end-use energy efficiency in Nigeria. The

interview process also served as a platform to understand key informant's perceived or experienced barriers in carrying out these activities. The information was also utilized in identifying ways of overcoming conflicts in institutional mandates and activities. Questionnaires were distributed to the contacted institutions. The questionnaires were used to substantiate interview responses, and they were designed in a format that will enable a coding scheme to reflect the level of engagement of each of the institution in the discharge of their mandates in the highlighted policy areas. Questionnaire data were analyzed using content analysis. The result of the analysis is presented below.

## **6.2 BACKGROUND**

In respect to energy efficiency in Nigeria, there is no clear public institution that has the lead role of coordinating activities. However, the Inter Ministerial Committee on Renewable Energy and Energy Efficiency (ICREEE), comprising members from key government MDAs directly engaged in end-use energy efficiency improvements such as the Federal Ministry of Power (FMP), Federal Ministry of Environment (FME), Federal Ministry of Science and Technology (FMST), Energy Commission of Nigeria (ECN), Standards Organisation of Nigeria (SON) is charged with the responsibility of the development and adoption of the NEEAP. A review of the institutional roles in the NEEAP reveals that some of the agencies have not been included as responsible institutions in the delivery of specific policy instruments in the NEEAP, especially in those roles considered as their respective statutory mandates. This may give rise to situations where important roles necessary for the advancement of the MEPS program are assigned to institutions that may not have enough capacity to deliver or implement these roles. It may also lead to situations where different ministries or government agencies perform similar roles which, if not properly coordinated, would create a complex and incoherent policy implementation structure. These situations may inhibit the development of an efficient policy framework necessary for effective uptake of MEPS in Nigeria. Many ministries have their energy department or agency that appears to develop their respective energy efficiency strategies which depicts the complexity of the sector.

The specific main actors in the appliance energy efficiency sub-sector and their mandates are presented in the following section. The section also highlights the roles that these institutions are assigned to execute, as detailed in the NEEAP and compares it with their statutory



mandates. The subsequent section presents the method used in analyzing interview and questionnaire data. The interpretation of all analysis is performed in the discussion section.

### **6.2.1 FEDERAL MINISTRY OF POWER**

The Federal Ministry of Power (FMP) is the main actor in the power sector and is responsible for the formulation, planning, coordination and implementation of policies and programs to advance the development of electricity generation from all sources of energy (GIZ, 2013, p. 19). The Ministry is headed by the Honourable Minister of Power, while the Honourable Minister of State for Power coordinates the operational activities and the Permanent Secretary serves as the accounting officer. The major mandate of the FMP is to develop and implement policies for effective generation, distribution and transmission of power that will drive the socio-economic needs of the country. This major mandate places the FMP basically on the supply-side of the electricity sector. The provisions of the following Acts guide the Ministry in the discharge of its duties: National Electricity Power Policy (NEPP) of 2001, the Electric Power Sector Reform (EPSR) Act of 2005, and The Roadmap Sector Reform Act of August 2010. In line with the EPSR Act of 2005, FMP engages in increasing renewable and clean electricity supply for the benefit of Nigerians (FMP, 2018). However, the activity of the FMP in this regard seems to be more on providing and coordinating enabling framework for private sector participation in delivering renewable and clean energy supply in Nigeria.

#### **Roles of the FMP in the NEEAP**

The FMP serves as one of the institutions that have been assigned with key roles on end-use energy efficiency in the NEEAP. These roles, which cut across the above listed policy areas of development of the NEEAP, setting and implementation of MEPS; specified functions in the area of monitoring, verification and enforcement of established appliance standards, advisory and support roles for MEPS, are listed below:

- Constituted member of the ICREEE. The ICREEE is constituted to develop the NEEAP and specific end-use efficiency policy measures in coordination with all existing policies and regulatory documents regarding renewable energy and energy efficiency in Nigeria. The FMP is mandated by the NEEAP to coordinate the activities of the ICREEE.
- Consultations with policy makers on the need to support energy efficiency. These consultations involve presentation of empirically-based findings derived through

baseline market research and cost-benefit analysis, focusing on the benefits of adopting energy efficiency in Nigeria.

- Formulate and adopt fiscal instruments such as tax cuts to support widespread diffusion of energy-efficient products.
- Development of energy efficiency standards and verification of compliance to set standards.
- Monitor importation and exportation of efficient products through periodic checks on importers and distributors. Other monitoring roles of the FMP include periodic checks of the market, keeping appliance inventories (which include collating data on products' characteristics such as information on country of origin, quantity imported, technical datasheet detailing the quality of products, importers name).
- Set and enforce penalties for non-compliance to the established standards and labeling (S&L) regulations.
- In the area of support roles, the FMP is mandated to launch public awareness campaigns geared towards enhancing public acceptance of energy efficiency and also liaise with other ministries and parastatals in ensuring compliance with regional and international standards.

Monitoring, verification and enforcement (MVE) roles of the FMP as detailed in the NEEAP is quite similar to the statutory mandates of the SON (see section 6.2.5). MVE roles are assigned only to the FMP in the Action Plan. It is expected that the SON that has the mandate and facilities for setting, implementation and verification of MEPS should have been responsible for the role of MVE in the NEEAP. It cannot be ascertained if the FMP has established facilities and capacity to conduct verification of appliance standards in line with established standards. Depending on the level of engagement in the monitoring, verification and enforcement exercises between the SON and the FMP, it may lead to duplication of duties and present a significant form of conflict. In respect to consultation roles with policy makers, it is expected that ECN that has direct mandate in the area of energy research (see section 6.2.3) should be involved correspondingly in the NEEAP for the role of consultation with policy makers. If the FMP does not synergies effectively with the ECN in consultations with decision makers, it may create room for an oversight in the discharge of this significant role. Also, the engagement of

the FMP in the setting of standards (as detailed in the NEEAP) presents a possible room for overlap with the statutory mandates of the SON (see section 6.2.5).

### **6.2.2 FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY**

The Federal Ministry of Science and Technology (FMST) main responsibility is enhancing the development and deployment of science and technological innovation in Nigeria. However, the ministry is also engaged in a variety of ways in the energy efficiency sub-sector in Nigeria. The mandate of the FMST as it relates to end-use energy efficiency is championed mainly through the Energy Commission of Nigeria (ECN), which in turn, is a major parastatal under the FMST. The FMST undertakes a supervisory role to the ECN. The specific mandates of the FMST include the provision of support for research and development (R&D) for efficient energy generation, transmission, distribution and utilization in an environment-compatible manner. Supports are mainly grants and the provision of research facilities. Through the ECN, the FMST carries out most of its research in the areas of energy efficiency and renewable energy. The research is guided by identified priorities in the area of energy efficiency and providing possible solutions which will inform the design of programs and their implementation. The Ministry also coordinates the formulation, implementation, monitoring and review of national renewable energy and energy efficiency policies. Irrespective of the FMST engagement in the support of R&D in the area of energy efficiency, and also having been listed as a member of the ICREE, the ministry has not been assigned with any particular role in the NEEAP.

### **6.2.3 ENERGY COMMISSION OF NIGERIA**

The Energy Commission of Nigeria (ECN) was established through the Energy Commission of Nigeria Act<sup>66</sup> No. 62 of 1979, as amended by Act No. 32 of 1988 and Act No. 19 of 1989. Pursuant to Section 5 of The Energy Commission Act, the ECN is charged with the strategic role of planning, development and coordination of national policies in the field of energy in all its ramifications (Energy Commission of Nigeria Act). By the provisions of Section 2 of the ECN Act, the commission should be directly under the presidency with the president as the chairman of the board of the commission. However, due to the issue of governance, the commission has

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<sup>66</sup> “An Act to establish the Energy Commission of Nigeria and to charge it with responsibility for coordinating and general surveillance over the systematic development of the various energy resources of Nigeria” (Energy Commission of Nigeria Act)

been moved within several ministries such as the FMP and the formally created Ministry of Energy. ECN is presently supervised by the FMST.

In line with its mandate on planning and development of national energy policies in all its ramifications, the ECN in 2003, developed the National Energy Policy (NEP) and a revised version of the NEP in 2013. The NEP provided the basis for the development of energy efficiency related policies in Nigeria. The establishment of the Commission, which commenced operations in 1989, was necessitated following the directives issued after the meeting of the Heads of the Economic Community of West African States (ECOWAS) held in Cotonou on 29 May 1982, which mandates Member States to establish Energy Commissions with the responsibility of coordinating and supervising all energy-related activities within Member States (ECOWAS, 1982, p. 50). The mandates of the Commission in the area of energy efficiency can be described as advisory or support roles, which specifically includes, conducting baseline research, pilot projects in selected residential homes and also carrying out energy audits in public institutions such as universities. These activities are aimed at providing empirical information on the benefits of energy efficiency and identifying major energy consuming sectors which will guide designing possible mitigation actions. ECN is also mandated to carry out sensitization programs to encourage widespread adoption of energy-efficient appliances and lighting products and discourage the use of incandescent light bulbs and promote MEPS and labels for household appliances. The ECN is also mandated to observe trends in innovations in technology for household appliances in order to take advantage of new and emerging energy-efficient technologies. Keeping trends with innovation in technology is quite crucial to the effectiveness of established standards because it guides the review of MEPS and ensures that standards are commensurate with technological improvements in products' efficiency levels. ECN mandates in the area of end-use energy efficiency could be regarded literally as strategic. There are six energy research institutes under the ECN of which the National Centre for Energy Efficiency and Conservation (NCEEC) located at the University of Lagos, Nigeria is directly responsible for research in end-use energy efficiency and conservation and the National Centre for Energy and Environment (NCEE) at the University of Benin, Nigeria coordinates research in the area of energy and the environment. Similar to the case of the FMST, the ECN (even though listed as a part of the ICREEE) was not identified in the NEEAP as one of the implementing institutions

responsible for any of the policy instruments described in the action plan, even in the area of supporting policies and important roles such as consultations with decision makers and other stakeholders, on the socio-economic benefits of energy efficiency as provided by parts of Section 5 of the ECN Act. It is expected that the ECN should be involved in creating such awareness campaigns due to their special engagement in R&D which should arm them with empirical information to sell energy efficiency. This issue was also investigated with key informants in the commission during interview sessions.

#### **6.2.4 FEDERAL MINISTRY OF ENVIRONMENT**

The Federal Government of Nigeria (FGN) established the Federal Ministry of Environment (FME) in 1999 with the main responsibility of protection of the natural environment from pollution and degradation and also to ensure sustainable development through the conservation of natural resources. The FME thus takes the lead role in formulating and implementation of national policies on environmental protection, sustainable use of natural resources and issues of response to climate change (FME official website).<sup>67</sup>

The FME is mandated for the preparation of a comprehensive national policy geared towards environmental protection and natural resources conservation which encompasses procedures for environmental impact assessment (EIA) of all developmental projects. This mandate is made possible under the provision of the EIA Act No. 86 of 1992 (EIA Act, 1992).<sup>68</sup> The Act requires major project developers (public or private) to subject their projects to the provisions of the EIA Acts (EIA Act, 1992). The FME represents the FGN in international climate change negotiations such as the Kyoto Protocol and the Conference of the Parties (COP) agreements, etc. In the area of energy efficiency, FME as a member of the ICREEE associates with other institutions in the committee in formulating effective renewable energy and energy efficiency policies and measures in order to help address inefficient use of energy in the country and to improve and create a more coherent policy framework. In addition, the FME is also responsible for the compilation and domestication of all environmental treaties signed or ratified by Nigeria and as well, monitoring the implementation and ensuring compliance to the provisions of such multilateral environmental agreements. Such environmental commitments include ensuring

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<sup>67</sup> Available online at: <http://environment.gov.ng/> (Last accessed on: 26.04.2019).

<sup>68</sup> An Act to set the general principles, procedures and methods to enable the prior consideration of environmental impact assessment on certain public or private projects, 1992 No. 86 (EIA Act, 1992).

compliance to allowed mercury contents in CFLs and safe disposal and management of burned-out CFLs in a manner that will not pose any threat to the environment.

The National Environmental Standards and Regulations Enforcement Agency (NESREA) is a parastatal under the FME through which the ministry enforces all environmental laws, guidelines, policies, standards and regulations in Nigeria (GIZ, 2013, p. 44). NESREA was established in 2007 through the NESREA Act (NESREA Establishment Act, 2007). Part II of the NESREA Act highlights the functions of the agency. A notable provision of the NESREA Act is Section 7 (c), which mandates the agency with the responsibility of prohibiting processes and use of equipment or technology that undermine environmental quality as well as to enforce compliance with provisions of various environmental regimes to which Nigeria is a signatory.<sup>69</sup> Consequently, the agency is mandated to set relevant standards and to implement and enforce charges as a result of non-compliance to the provisions of the established standards. The NEEAP assigned key roles to both the FME and NESREA in the area of appliance energy efficiency. In accordance with the statutory mandates of the FME and NESREA, these activities are mainly focused on support and environmentally sound management measures.

#### **Roles of FME and NESREA in the NEEAP**

- The FME is mandated in the NEEAP to commence a phase-out initiative of mercury-based CFL bulbs in Nigeria and introduce LED bulbs as alternative.
- Initiate demonstration projects and awareness campaigns targeting final consumers and decision makers on the need for environmentally sound collection and disposal of end-of-life efficient lamps and products.
- Development and adoption of national regulation for environmentally sound management of spent efficient lamps and appliances. In this regard, NESREA has initiated the Extended Producer Responsibility (EPR) program that requires importers, producers and distributors of products to ensure the life cycle management of their products by taking the products back at their end-of-life.
- Setting up of collection and disposal system or organizations for burned-out energy-efficient light bulbs and develop incentives for consumers to encourage appropriate disposal of spent lamps.

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<sup>69</sup> Section 7 (c) of the NESREA Establishment Act, 2007.

- NESREA is also mandated to engage in consultation with political bodies and utilities on drafting incentive schemes and to develop and introduce instruments (such as utility programs, credit schemes) to finance energy-efficient equipment.

The engagement of NESREA in setting and enforcing standards, especially those related to the allowed mercury content in CFLs, may constitute a form of conflict with the assigned roles of the FMP and the statutory mandates of the SON (see section 6.2.5). Furthermore, if not properly coordinated, the presence of different monitoring and compliance institutions may present a form of bureaucracy which could complicate the process of confirming appliance standards.

### **6.2.5 STANDARDS ORGANISATION OF NIGERIA**

The Standards Organisation of Nigeria (SON) was established by Act 56 of 1971. The Standards Organisation of Nigeria (SON) Act, 2015 repeals previous Acts and provides additional functions for the organization (SON Act, 2015). Subject to Sections 4 and 5 of the SON Act 2015, the agency is charged with the responsibility of establishing, promotion and implementation of standards and quality in regards to products, manufacturing and metrology services in Nigeria (SON Act, 2015). SON is under the leadership of the Federal Ministry of Industry, Trade and Investment (FMITI). SON's statutory mandate is to ensure enforcement and compliance with established standards and best practices. SON is a part of the ICREEE and in line with its official mandate; the NEEAP involves the SON as an implementing institution for the following policy measures:

- Development and adoption of MEPS and labels based on the results of the baseline market assessments.
- Harmonization of MEPS with ECOWAS standards.
- Ensuring standards are aligned with international best practices.
- Conduct impact assessment of established or proposed standards and assessment of energy efficiency improvement potential of selected appliances.

In reference to SON's statutory mandates, the agency is authorized to develop MEPS for appliances and also carry out testing of appliances to ascertain compliance with established standards. In line with verification of compliance to the established standards, Section 5(n) of the SON Act, 2015 authorizes the agency to establish and maintain test laboratories necessary

for conducting appliance conformity tests (SON Act, 2015). Section 5 (t) of the SON Act also mandates the agency to conduct periodic checks on products in the market and confiscate appliances that do not meet the required standards (SON Act, 2015). However, in as much as SON is officially engaged in these activities, with established capacity and facilities to engage in the verification of appliance standards, they are not included in the NEEAP in the monitoring, verification and enforcement (MVE) roles. Depending on the level of engagement of the FMP in the roles of MVE as assigned in the NEEAP, this may present possible conflict and could affect the smooth and effective monitoring and compliance verification exercises of appliances.

From the analysis of the institutional mandates of the relevant ministries and parastatals involved in the energy efficiency sub-sector, it could be interpreted that the FMP, FME, NESREA, ECN under the FMST, SON all have relevant official mandates to support the widespread diffusion of energy-efficient appliances in the country. However, there seems to be a lack of proper coordination and consistency in assigning institutional roles in the NEEAP in line with the official statutory mandates of the respective institutions. This is perceived as being capable of leading to duplication and overlaps in activities that are carried out by these agencies and institutions. Concerns on these potential sources of overlaps, as highlighted in table 6.1, constitutes part of the interview discussions with key informants in the respective institutions. The need to investigate further on the discharge of institutional roles prompted the use of questionnaires to understand the level of engagement of these institutions in respect to their official mandates and roles in the NEEAP.

Table 6.1 presents an overview of the analyzed institutions highlighting their roles in the NEEAP and nature of relationships. Based on the review of the institutions' mandates and assigned roles in the NEEAP, the table highlights potential sources of overlaps in activities and identified gaps among the various actors.



Table 6.1 Overview of institutional roles and mandates

<b>Institution</b>	<b>Mandate</b>	<b>Relationship with other institutions</b>	<b>Potential sources of overlap</b>	<b>Gaps</b>
Federal Ministry of Power (FMP)	Development and implementation of policies that will ensure the provision of reliable and sufficient power supply to drive the socio-economic development of the country	Heads the ICREEE team	FMP's assigned roles in MVE if not properly managed may be a source of overlap and conflict with the statutory mandates of SON and NESREA.	Absence of a dedicated energy efficiency unit and test laboratories
Federal Ministry of Science and Technology	Mainly to enhance the development and deployment of science and technological innovation in the country	Part of the ICREEE team. Relationship with other institutions in the area of energy efficiency is through the ECN		
Energy Commission of Nigeria (ECN)	Planning and coordination of national policies in the field of energy in all its ramifications	A member of the ICREEE team and partners with all members of the ICREEE in developing energy policies for the country		Should be actively engaged in consultation with decision makers on the need to mainstream energy efficiency.
Federal Ministry of Environment (FME)	Protection of the environment and natural resources for sustainable development	A member of the ICREEE.		
National Environmental Standard and Regulatory	Protection of the environment and conservation of natural	Relates with stakeholders and institutions in the development	Statutory roles in setting and verification of standards may	Measures to verify compliance with mercury content

Agency (NESREA)	resources	of environmental standards and regulations based on international best practices	present a form of conflict with the activities of SON and the assigned roles of the FMP in the NEEAP.	levels in CFLs are still in their planning stages
Standard Organization of Nigeria (SON)	Development of standards and ensures the compliance of established standards.	Part of ICREEE and partners with stakeholders and institutions in the development and enforcement of standards	Though SON's mandates appear unique, there is a potential overlap in mandate with the FMP in the area of enforcement of compliance to standards. Also possible overlaps exists with NESREA on standard setting	

### 6.3 ANALYSIS OF INTERVIEW AND QUESTIONNAIRE DATA

The interviews and questionnaires were employed to validate the outcome of the review conducted on institutions' mandates and their assigned roles in the NEEAP. The analysis of the interview data was based on the researcher's assessment and questionnaire data were analyzed using content analysis. Content analysis, as illustrated in figure 6.1, involves a routine review of data to become very familiar with its content, operationalizing or defining how variables (policy areas) will be measured and from the researcher's assessment, identify which of these policy areas an overlap would present significant impact. Furthermore, the questionnaire was prepared to enable a coding scheme. The coding scheme reflects how active institutions are in each of the policy areas and it is categorized as: very active; moderately active; not active and no role. The coding scheme was then quantified as, very active (5); moderately active (3); not active (1); and no role (0). The institutions were grouped to reflect the institution's level of engagement in each policy area and the result represented in form of a matrix for a clear demonstration of identified possible overlaps in policy mandates of the respective institutions.

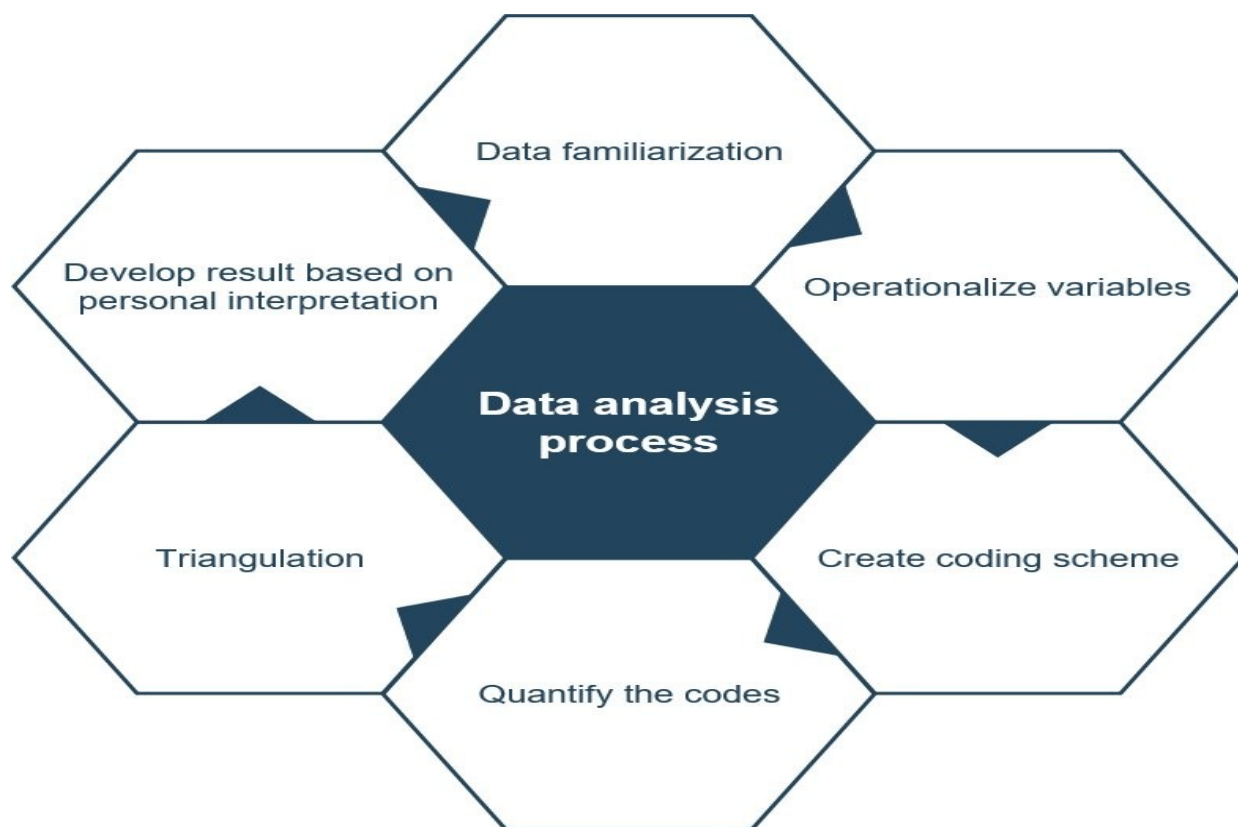


Figure 6.1 Questionnaire data analysis process (Source: Produced by author).

## 6.4 RESULTS AND DISCUSSION

The analysis of the interview data confirms that all the contacted relevant ministries and government agencies constitute members of the Inter-Ministerial Committee on Renewable Energy and Energy Efficiency (ICREEE) and thus, participated in the development of the NEEAP. From the questionnaire response, all institutions engaged actively in the activities of the ICREEE. FMP reported a moderate role in the consultation with decision makers on the need to mainstream energy efficiency in the country's energy policies. ECN did not report any level of activity in the area of consultations with decision makers. This could be because the NEEAP did not mandate them to engage in this activity. On further inquiry, FMP has not been able to synergize properly with ECN which may likely be the reason ECN is not assigned with any roles in the NEEAP. This poor synergy is attributed to varying internal interests of both institutions. However, ECN has conducted several baseline research and pilot projects such as energy audit of public buildings in Abuja and institutions of higher learning, free distribution of CFLs in

selected estates in Abuja to create initial awareness for efficient lighting, development of National Energy Audit Templates for use in residential and public buildings. Data from these activities should be necessary during consultations with decision makers.

In the area of appliance energy efficiency policy implementation (MEPS), SON's reported activities and level of engagement indicate a unique and active role in the area of setting of appliance standards. FMP and NESREA, however, did not report any activity in the setting of appliance standards. This indicates a certain level of inconsistency in the action plan. Based on questionnaire responses, the activities of other institutions in this regard is interpreted as support roles, which involves conducting baseline research by ECN that informed the setting of appliance standards and grant provisions by FME to support end-use energy efficiency projects. Considering monitoring, verification and enforcement of the NEEAP with a particular focus on developed appliance standards, SON confirms engagement (active roles) in the MVE activity. SON's reported activities in the monitoring of appliance compliance to MEPS include periodic checks of major electronics markets, shops and importers' warehouses. The agency also liaises with the customs in monitoring appliances imported into the country and reports that vehicles suspected of conveying appliances can be stopped at random and searched. These monitoring activities are in line with the provisions of Part VII of the SON Act (SON Act, 2015). For enforcement, SON reported activities include confiscating products that do not meet MEPS levels. Pursuant to section 31 of the SON Act, such defaulters are mandated to pay various ranges of fine. Section 31 of the SON Act also empowers SON to take extra-disciplinary measures, such as court prosecution, conviction to a fine or imprisonment of defaulters who evade the payment of levies (SON Act, 2015). Reported verification process involves registration of products on the agency's online portal to request for product certification and submission of the products for verification tests at SON's designated test facilities. A certificate of compliance is issued which must be presented before the products can be cleared from the wharf. Compliance test for the products is basically to verify if maximum unitary energy consumption of the appliance, under specified test conditions, meets established energy consumption threshold for that type of appliance. For instance, for light bulbs, verification tests include confirming the lamp's rated wattage, efficacy, lumen output, etc. The number of product samples to be submitted for the various tests are determined by SON. Based on the

questionnaire response, SON did not indicate any activity in verifying lamp’s mercury (Hg) content levels. NESREA reported that measures for the verification of compliance to mercury content level allowed in CFLs manufactured or imported into Nigeria are still in their planning stages. This could be interpreted to mean that confirmation of mercury content levels in CFLs has not commenced as at the time of this research. FMP indicated a moderate engagement in the MVE role but did not provide details or their implementation strategies of MVE roles. As a result, it could not be ascertained if FMP has the capacity and facilities to engage in MVE roles. SON seems to be the only agency actively engaged in verifying compliance of products to the established MEPS in Nigeria. As a result, no clear overlap or conflict in appliance MVE roles is identified. However, depending on how the planned verification of mercury content levels in CFLs is coordinated between NESREA and SON, it may present a source of overlap and introduce a certain level of bureaucracy in the process of appliance verification test exercise. Table 6.2 is a matrix representation of indicative roles played by key institutions in championing appliance energy efficiency as deduced from questionnaire responses.

Table 6.2 Indicative roles played by key institutions in championing end-use energy efficiency

Key MDAs	Policy areas			
	Policy planning (development of the NEEAP - member of ICREEE)	Setting and Implementation of appliance standards (MEPS)	MVE (NEEAP)	Advisory and support services (appliance energy efficiency related)
FMP	●		●	
FME	●			●
FMST	●			
ECN	●			●
SON	●	●	●	●
NESREA	●		●	●

- = Active role and possible overlap.
- = Active role, but no conflict.
- = Moderately active.

## **6.5 CHAPTER CONCLUSION**

As earlier pointed out, the assessment performed in this chapter shows that certain institutional roles as detailed in the NEEAP are not properly aligned with official institutional statutory mandates. This could lead to multiplication of duties and to situations where institutions with the capacity to perform specific roles for the advancement of end-use energy efficiency are not adequately engaged in such roles. For instance, ECN as a research-based agency is strategically positioned to create awareness for end-use energy efficiency and thus, should engage more in consultations with decision makers on the need for end-use energy efficiency to be mainstreamed in the country's energy policies. Although no clear conflicts or overlaps were identified, potential sources for such overlaps exist, especially in MVE roles, as highlighted in table 6.2. The reported poor synergies between ECN and FMP should be addressed to enhance cooperation between these two institutions which is necessary for championing end-use energy efficiency especially in Nigeria where the concept of appliance energy efficiency is not yet well established.

## **7. REVIEW OF RELEVANT INTERNATIONAL ENVIRONMENTAL CONVENTIONS AND PROTOCOLS.**

### **7.1 INTRODUCTION TO CHAPTER SEVEN**

This chapter provides a deep insight into International Environmental Conventions and Protocols that are relevant to improving end-use energy efficiency. The chapter provides key aspects of international environmental agreements signed or ratified by Nigeria to underscore binding commitments that can be realized through the implementation of appropriate end-use energy efficiency policy instruments. The chapter ends with the discussion on improving appliance energy efficiency in the context of the discussed international environmental conventions.

### **7.2 BACKGROUND**

Conventions are internationally recognized global legal instruments and thus, are considered binding. It defines the responsibilities of all the states that are parties to the convention. By signing and ratifying a convention, countries are committed to adhering to the principles established in the document. Signing a convention is usually the first process towards its

ratification. By ratifying a convention, contracting parties or member states, promise to uphold the principles of the convention and adhere to the legal binding obligations that it specifies. By ratification, member states are committed to develop or adopt policies and institutional structures towards the goals of the convention. Countries that have ratified a convention are required to regularly report on their national efforts and successes achieved in the implementation of the agreements reached in the convention. Conventions usually undergo developments, in the form of amendments. These amendments are usually decided during the statutory meetings of member states, referred to as the Conference of Parties (COP) and require the consent of the parties. This process entails consultative sessions which may lead to the adoption of new agreements that were not previously included in the parent convention. A convention normally enters into force when a predetermined number of the contracting parties have signed and ratified it. More than 700 multilateral international agreements and conventions deal with environmental issues (InfoResources Focus, 2005, p. 3). These conventions are mutually supportive in their roles towards environmental protection. However, the selected environmental conventions are based on their relevance to the end-use appliances investigated in this dissertation. In other words, those conventions that address issues of reduction of greenhouse gas emissions and other environmental concerns to which the use of the investigated household appliances contribute to. These include; The Montreal Protocol and the Kigali Amendment, The Minamata Convention on Mercury, and the Paris Climate Agreement. The review of these conventions is to elucidate information on how emissions resulting from the use of these appliances are addressed internationally and also to understand clearly, the extent their use impact global climate change. Based on the case study survey, this chapter will also discuss local practices and conditions that may hinder national efforts towards the binding commitments reached in these conventions and which may also affect the widespread diffusion of energy-efficient appliances. This will highlight the need for the government to be proactive in their actions to advance end-use energy efficiency and contribute to the overall global efforts to fight climate change and enhance sustainable development.

## 7.3 REVIEW OF INTERNATIONAL ENVIRONMENTAL REGIMES NIGERIA IS A SIGNATORY

### 7.3.1 THE PARIS CLIMATE AGREEMENT

With the commitment to undertake and communicate more ambitious efforts towards global response to climate change, parties to the United Nations Framework Convention on Climate Change (UNFCCC) during the twenty-first session of the Conference of the Parties (COP 21) and the eleventh session of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol, held in Paris, France from 30 November through 11 December, 2015 negotiated the Paris Climate Agreement.<sup>70</sup> The main goal of the Paris Agreement is to strengthen universal response to the dangers of climate change by maintaining a global temperature rise this century well below 2°C above pre-industrial levels and to ensure efforts to limit the temperature increase even further to 1.5°C; furthermore, to enhance effort to adapt to the impacts of climate change and advance climate resilience and sustainable development in a manner that does not affect food production (...).<sup>71</sup> The Paris Agreement entered into force on 4 November 2016.<sup>72</sup> Pursuant to Article 3 of the Paris Agreement, parties are now required to review and update their Intended Nationally Determined Contributions (INDCs) and submit them as Nationally Determined Contributions (NDCs) to reflect high possible ambitions towards reducing GHG emissions and to strengthen these efforts in the coming years (UNFCCC, 2015).<sup>73</sup> Information from the United Nations Treaty Collection (UNTC)<sup>74</sup> shows that Nigeria became a signatory to the Paris Agreement on 22 September 2016 and communicated its first Nationally Determined Contribution (NDC) on 16 May 2017. The Nigeria's NDC demonstrates ambitious commitment to contribute to the Paris Climate Agreement. From implementation period of 2015, the goal of the Nigerian government, according to the NDC, is to reduce its GHG

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<sup>70</sup> The Paris Agreement builds upon the activities of the United Nations Framework Convention on Climate Change (UNFCCC) and for the first time, gathers all nations into a common goal to initiate ambitious efforts to combat climate change and adapt to its impacts; it also calls for improved support to assist developing countries to achieve this common goal (UNFCCC, 2015).

<sup>71</sup> Paris Agreement Article 2 Section 1 Sub-sections (a) (b) (UNFCCC, 2015).

<sup>72</sup> The Paris Agreement entered into force on 4 November 2016 after achieving the stipulated threshold of at least 55 Parties to the Convention, which together represents at least 55 % of global GHG emissions have ratified the agreement. - Article 21 (1) of the Paris Agreement.

<sup>73</sup> This includes the requirement that all Parties enumerate measures to reduce emissions and regularly report on their emissions and their implementation efforts – Paris Agreement, Article 3 (UNFCCC, 2015).

<sup>74</sup> The United Nations Treaty Collection (UNTC) is a global online portal providing access to detailed information as regards the activities of the Treaty Section. Available online at: [https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg\\_no=XXVII-7-d&chapter=27&clang=\\_en](https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en) (Last accessed on: 12.12.2018).



emissions by 20 % unconditionally and 45 % conditionally (with international support – finance, technology and capacity building) compared to a BAU scenario (Nigeria NDC Report, 2017, p. 9). The NDC report reveals that under the BAU scenario, emissions are expected to reach 900 million tonnes CO<sub>2</sub> equivalent (MtCO<sub>2</sub>e) by 2030.<sup>75</sup> In 2015, about 400 MtCO<sub>2</sub>e were emitted; considering an unconditional mitigation objective scenario, emissions should be capped at 720 MtCO<sub>2</sub>e (20 % below BAU) by 2030. Based on available information on the World Resources Institute (WRI) online data explorer, Nigeria’s greenhouse gas emissions (excluding land use), exceeded 296 MtCO<sub>2</sub>e in 2012 (WRI, 2014). This represents about 35 % increase in GHG emissions relative to 2015 estimates. If this increasing trend continues, capping emissions at 720 MtCO<sub>2</sub>e by 2030 may not be achievable.

Information from a recent study shows that the full implementation of all NDCs from the parties to the Paris Climate Agreement, would not be enough to limit the rise in global temperature to 2°C let alone to 1.5°C (Munzinger, et al., 2016, p. 10). This means that Contracting Parties to the Paris Agreement, must not only ensure the full implementation of their current NDCs, but also make significant effort to increase their ambition levels in successive national mitigation actions. Parties are mandated to submit a revised version of their NDCs every five years starting from 2021 or earlier (Article 4 paragraph 9). This calls for the need to embark on early mitigation actions as well as, comprehensive and concrete implementation plans. This also underscores the need for continuous evaluation of mitigation measures based on previously established targets. The assessment of existing mitigation measures would assist in revealing the success rate of the measures towards achieving established targets and also, such assessment will provide information that will assist in enhancing existing mitigation measures and/or planning for more stringent actions.

### **7.3.2 THE MONTREAL PROTOCOL**

The Montreal Protocol, a Protocol to the Vienna Ozone Convention,<sup>76</sup> was adopted in Montreal on 16 September, 1987 to reduce the production and consumption of certain substances that

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<sup>75</sup> The report does not specify if emissions include Land Use Change and Forestry (LUCF).

<sup>76</sup> The Vienna Ozone Convention, which was adopted on 22 March 1985 and entered into force on 22 September 1988, is a framework treaty for the international efforts to protect the globe’s ozone layer (Art. 2 para 1, Vienna Ozone Convention). In reference to Albrecht (2016, p. 97), The Vienna Ozone Convention, served as the basis for the Montreal Protocol and both the Vienna Ozone Convention and the Montreal Protocol became the first universally ratified treaties in the history of the United Nations, having been ratified by 193 UN member States, the European Union, the Holy See, Cook Islands and Niue.

can significantly deplete and/or modify the ozone layer in such a way that is likely to present adverse impacts on human health and the environment. The Protocol, which entered into force on 1 January 1989 on the provisions of Article 16<sup>77</sup> of the Montreal Protocol, effectively controls the use of ozone depleting substances (ODS)<sup>78</sup> such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) due to their high ozone depleting potentials (ODP)<sup>79</sup> and high global warming potentials (GWP).<sup>80</sup> Pursuant to Article 2 of the Protocol, Parties are mandated to stop the production and/or consumption of these substances. These fluorinated gases (CFCs or HCFCs) are used partially as refrigerants in cooling applications such as refrigerators and air conditioners. In reference to Munzinger, et al. (2016, p. 8) the Montreal Protocol, resulted in a global phase-out of CFCs by 2010 and the use of HCFCs (initially employed as alternatives to CFCs) has been banned in developed nations since 2010. However, compliance to the ban of HCFCs has been delayed in developing nations and as a result, HCFCs are still widely used in these countries (Munzinger, et al., 2016, p. 8). The delay in the ban of HCFC in developing nations is to satisfy basic domestic needs and to allow for industrial rationalization between developing and developed nations. It is reported that the gradual phase-out of HCFCs in developing nations started in 2013 and a 35 % reduction in the production and consumption of HCFCs is expected by 2020 and subsequently, a 100 % phase-out is targeted by 2040 (Munzinger, et al., 2016, p. 8).

Nigeria became a signatory to the Montreal Protocol on 31 October 1988 and submitted instruments of ratification on 29 January 1989 and as such, Nigeria is mandated to comply with the provisions of the Protocol and participate at statutory meetings.

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<sup>77</sup>Article 16 of the Montreal Protocol highlights that the Protocol shall come into force provided at least eleven (11) instruments of ratification of the Protocol have been deposited by states or regional economic integration organizations representing at least two-thirds of 1986 estimated global consumption of the controlled substances... (Art. 16 para 1 Montreal Protocol).

<sup>78</sup>As the name implies, ODS are those substances that deplete the ozone layer exposing the earth to high ultraviolet radiation from the sun and leading to global warming (UN Treaty Series, 1989).

<sup>79</sup>Ozone depleting potential (ODP) of a substance is the relative measure of the depletion it can cause to the ozone layer, CFCs have ODP of 1.0 (UN Treaty Series, 1989, p. 40)

<sup>80</sup>The United States (US) Environmental Protection Agency (EPA) defines global warming potential (GWP) of a gas as the measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), compared to carbon dioxide which has a GWP of 1.0 (EPA official website). GWP for carbon dioxide serves as a baseline for other GWP values and simply, the higher the GWP, the more warming the gas causes. The GWP for CFCs and HCFCs can be in the thousands or tens of thousands. In reference to the IPCC 5<sup>th</sup> Assessment report (AR5) adapted in the greenhouse gas protocol report, CFC-12 has a GWP (100-year) of 10,200 (Greenhouse gas protocol, 2016, p. 1).

### **7.3.3 THE KIGALI AMENDMENT TO THE MONTREAL PROTOCOL**

Following the phase-down of HCFCs under the Montreal Protocol, they were increasingly replaced by hydrofluorocarbons (HFCs) as refrigerants in cooling applications. Although HFCs have no ozone depleting potential they, however, have a significant global warming potential (GWP). Specifically, HFCs have a high GWP of about 4000 CO<sub>2</sub>e (Munzinger, et al., 2016, p. 3). HFCs have been reported under the United Nations Framework Convention on Climate Change (UNFCCC) as a greenhouse gas (GHG) (Munzinger, et al., 2016, p. 3). The increasing use of HFCs as refrigerants, if not regulated, would contribute significantly to global GHG emissions which would have adverse effects on the 2°C ultimate goal set out in the Paris Agreement. Recognizing this fact, Parties to the Montreal Protocol during the 28<sup>th</sup> session of the Conference of the Parties (serving as the meeting of the Parties to the Montreal Protocol) in Kigali, October 2016, agreed to globally phase-down the production and consumption of HFCs over the next three decades. In reference to the analysis by Velders, et al. (2012) in Munzinger, et al. (2016, p. 3), the Kigali Amendment has the potential to avoid about 90 % of the temperature increase that HFCs could have caused. Nigeria has signed all related successive amendments to the Montreal Protocol (namely: The Copenhagen, London, Montreal and Beijing amendments), and it is expected that Nigeria will also sign and ratify the Kigali Amendment.

### **7.3.4 THE MINAMATA CONVENTION ON MERCURY**

In reference to Article 1 of the Minamata Convention on Mercury, the convention aims to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. The Convention recognizes mercury-added products, such as compact fluorescent lamps (CFLs) with a mercury content exceeding 5 mg per lamp, as potential sources of environmental and health hazards. The Convention was adopted on 10 October 2013 and entered into force on 16 August 2017 subject to the provisions of Article 31 (1)<sup>81</sup> of the Minamata Convention. The accumulation of burned-out CFL lamps, if not properly managed, will constitute a huge source of mercury waste. Article 11 (3a) of the Minamata Convention mandates Parties to take appropriate measures so that mercury waste is managed in an environmentally sound manner. Furthermore, Parties are mandated by the provisions of Article

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<sup>81</sup>Article 31 (1) of the Minamata Convention on Mercury states that the Convention shall enter into force ninety days after the date of deposit of the fiftieth instrument of ratification, acceptance, approval or accession was communicated (UN Treaty Series, 2013, p. 36).

18 paragraph 1 (a) and (b), to create public awareness on the health and environmental effect of mercury and mercury compounds and the need to limit exposure to mercury compounds. In reference to Annex A Part I of the Minamata Convention, all CFLs that are  $\leq 30$  watts with a mercury content exceeding 5 mg will be phased out in 2020 (UN Treaty Series, 2013, p. 39). Nigeria, though not yet ratified the Convention, became a signatory on 10 October 2013.

Mercury, once anthropogenically introduced, is persistent in the environment and can bioaccumulate in ecosystems (UN Treaty Series, 2013, p. 1). The World Health Organisation (WHO) considers mercury as a significant substance of major public health concern. Information retrieved from the official website of the WHO, shows that exposure to mercury, even small amounts, may pose various serious health risks such as effects on the nervous system which may lead to neurological and behavioral disorders, impacts on the digestive and immune systems, and on significant body organs such as the lungs, kidneys and the skin, which may be fatal (WHO official website, 2019).

#### **7.4 CHAPTER DISCUSSION**

Economic and population growth, electrification programs, and rising ambient temperature will drive an increase in demand for electrical appliances such as light bulbs, refrigerators and air conditioners in Nigeria. The growing use of these appliances will contribute to an increase in GHG emissions from two different perspectives; firstly, these appliances consume electricity which is mainly generated through the combustion of fossil-based fuels (natural gas), which consequently results to huge amount of CO<sub>2</sub> emission (indirect emissions). Secondly, fluorinated gases used as refrigerants in cooling applications (especially older appliances) are sources for substances with huge global warming and ozone depleting potentials. Also, since it is technically not possible to produce mercury-free CFLs at the moment, CFL disposal, if not handled in an environmentally sound manner, will lead to other environmental and health concerns. Commitment towards international regimes, such as those discussed in this chapter, compels contracting parties like Nigeria to embark on a sustainable path to economic development and to create enabling institutional structures and policy measures to drive green growth. The discussion section is then focused on the use of inefficient lighting, refrigerators and air conditioners in Nigeria in the context of the reviewed international environmental regimes. As performed in the analysis in chapter 5, the section highlights the potential emissions reductions

contribution from the current MEPS regulation to the emissions reduction targets stipulated in Nigeria's NDC report. It also discusses current local situations in the appliance-use sector that may inhibit national efforts towards commitment to the reviewed relevant international environmental protocols. The identified situations highlight issues that need to be addressed with effective policies and underscores the role that the increase in end-use energy efficiency can play in maximizing climate benefits in Nigeria.

#### **7.4.1 IMPROVING ENERGY EFFICIENCY OF REFRIGERATOR AND AIR CONDITIONER IN THE CONTEXT OF THE MONTREAL PROTOCOL AND PARIS CLIMATE AGREEMENT**

Based on the assessment conducted in chapter 5 of this dissertation, refrigerator-freezers and room air conditioner contributions to mitigating CO<sub>2</sub> emissions (considering current standards) is relatively low when compared to the mitigation potential of lighting alone. Refrigerator-freezers and room air conditioners will contribute approximately 12 % and 0.8 % respectively of the estimated cumulative emissions savings of 15.14 MtCO<sub>2</sub> from the implementation of the current standard for the covered products. This would amount to 1.1 % of the emissions reduction target of 179 MtCO<sub>2</sub> highlighted in Nigeria's NDC. However, emissions reduction of air conditioners and refrigerators would improve if more stringent MEPS levels are introduced. In this scenario, emissions mitigation from the modeled refrigerator-freezer type will contribute approximately 22 % of the total emissions savings from the covered products and emissions savings potential from the modeled room air conditioner would improve to approximately 4.5 % of the total emissions savings from the covered products. This would amount to approximately 3 % of the targeted emissions savings in the NDC report. In line with the call for Parties to the Paris Agreement to adopt more stringent policy measures in order to realize commitments and pledges, institutionalizing more aggressive MEPS could be a means of keeping the country on track of improving economy-wide energy efficiency and pursue the aims of meeting up with the target and pledges as highlighted in the NDC. The estimated savings could be regarded as conservative considering the fact that the old appliances would consume more electricity than the assumed baseline consumptions and also because old and/or used appliances often contain environmentally damaging fluorinated gases as their refrigerant (U4E policy guide series, 2017b, p. 68). The use of environmentally damaging refrigerants contributes significant direct emissions in the life cycle of such old appliances.

The process of domestication of the Montreal Protocol in Nigeria, which commenced in 2004, involves the control of importation and use of appliances that contain ozone-depleting substances and substances with high global warming potentials (National Ozone Office website). The importation of appliances such as old, used and especially, non-functioning refrigerators and air conditioners are controlled under this domestication program. In addition to being a potential source of ozone-depleting substances and substances with high global warming potentials, old and used refrigerators and air conditioners will also consume more energy during use. In reference to the Nigeria National Ozone Office (NOO), a bill for an Act to provide for the protection of the ozone layer and the control of the import, export and use of ozone-depleting substances was drafted in 2004 (National Ozone Office website). A recent study reported that irrespective of the control on the importation of used electrical appliances, about 2300 tons and 1500 tons respectively of used and/or defect refrigerators and air conditioners were imported into the country in 2016 (Odeyingbo, et al., 2017, p. 48). The use of fairly-used appliances in households and the continued importation of used appliances could be an indication that legal compliance is not appropriately enforced. From the stated values, it is estimated that 40 % of the air conditioners and 33 % of the refrigerators are found to be non-functional (Odeyingbo, et al., 2017, p. 48). However, the control on the importation of these appliances might have led to a drop in their imports but those that end up into the country are most likely inefficient and may contain environmentally hazardous substances. The non-functional types are sold at lower prices to resellers (who repair the non-functioning devices before they resell it at a higher price to end-users) or to scrap dealers that dismantles the appliances and sells their parts (such as compressors) to local repairers. In Enugu, there is an observed high presence of local unprofessional technicians with the capacity to repair these products at considerably low charges. Most of these technicians who obviously, do not know the names of the gases nor their impacts on the environment may lack the capacity or knowledge to adopt adequate precautions when servicing, repairing or dismantling the appliances as scraps. A recent study has identified stages in the life-cycle of a refrigerator and air conditioner that significant emissions occur. According to the study, 66 % of emissions occur during operations and maintenance services and 33 % emissions occur during disposal and dismantling and 1 % during manufacturing, filling, delivery (Munzinger, et al., 2016, p. 6). The

use and servicing of cooling applications that contain fluorinated gases (such as old and used refrigerators and air conditioners) thus, presents a potential source of emission of ozone-depleting substances and/or substances with high global warming potential. These emissions will be exacerbated when adequate precautions are not taken during maintenance, dismantling and disposal of the appliance. Old refrigerators and room air conditioners, including those purchased as fairly-used, still constitute a considerable large number of existing stock in surveyed households (see chapter 5). Based on the household survey, more than half (56 %) of the different types of refrigerators in the surveyed households were purchased as used appliances (see figure 5.12). Considering the age of these appliances, it is most likely they may contain regulated gases and are also, probably serviced or refilled using banned gases. The low cost of purchase of used refrigerators and air conditioners in Nigeria, when compared to the cost of buying new and efficient types of the appliance as well as the low cost of repairs and maintenance, motivates most buyers into engaging in these transactions. As a result, many end-users, may likely not voluntarily replace their old and inefficient refrigerators or air conditioners with new and efficient types without government's support programs. Furthermore, the high-skill level of the local refurbishing market (with capacity to fix most technical defects in non-functioning electrical appliances at very low service costs) coupled with other factors such as poor enforcement of the control on importation of used appliances, create a huge market which serves as a pull factor for the continued importation of used electrical appliances.

From the above presentation, it could be interpreted that the control on the importation of used electrical appliances (air conditioners and refrigerators) alone may likely not be able to lead to a successful phase-down of HCFCs and CFCs in the country. Aligning the control on the importation of used refrigerators and air conditioners with effective MEPS and supporting policies, such as rebate programs or financial incentives to overcome the burden of high initial investment costs of energy-efficient products, would ensure that appliances coming into Nigeria are climate friendly and thus, result in maximizing national efforts in the control and phase-down of gases and substances with high ozone depleting and global warming potentials.<sup>82</sup>

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<sup>82</sup> Studies have shown that most new refrigerators use environmentally friendly refrigerants such as isobutane (HC 600a) whose direct emissions impact is negligible (U4E policy guide series, 2017b, p. 63). Isobutane refrigerants accounted for approximately 95 % of refrigerator sales in the EU in 2014 (U4E policy guide series, 2017b, p. 68). Isobutane is flammable, so precautions should be taken during servicing and disposal (U4E policy guide series, 2017b, p. 66).

However, careful policy attention is needed to ensure the safe disposal and proper management of gases from old appliances returned during rebate programs. Appropriate incineration technology for the retrieval, recycling or destruction of gases from old appliances is available (U4E policy guide series, 2017b, p. 68). Awareness campaign and capacity building targeting technicians on the use and necessary precautionary measures to be taken during servicing and removal of gases from these appliances are some of the policy measures to control the release of gases with global warming and ozone depleting potentials.

#### **7.4.2 IMPROVING LIGHTING EFFICIENCY IN NIGERIA IN THE CONTEXT OF THE PARIS CLIMATE AGREEMENT AND THE MINAMATA CONVENTION ON MERCURY**

The use of inefficient incandescent light bulbs consumes more electricity than when efficient light bulbs are used for lighting applications and thus leads to more CO<sub>2</sub> emissions. As shown in table 5.1, there is a considerable high presence of incandescent light bulbs in the surveyed households. The policy impact analysis conducted in chapter 5 of this dissertation, underscores the huge energy and emissions savings potential of light bulbs when compared to refrigerators and air conditioners. The estimated potentials point to the fact that effective implementation of MEPS would contribute to the realization of Nigeria's emissions reduction targets as communicated in the national NDC towards commitment to the Paris Climate Agreement.

The high presence of incandescent lamps in the case study area can also be interpreted as a high market-size potential for CFLs. Mercury is an essential element in the functioning of CFL lamps because mercury helps to maintain the efficiency of the light bulb. No mercury is released when the light bulb is in use and not broken; however, information from the official website of the United States (US) Environmental Protection Agency (EPA) shows that CFLs can release mercury vapor when broken or if they are improperly disposed at the end of their useful life periods.<sup>83</sup> There is no observed presence of CFL disposal points or centers in the studied area and careless disposal of burned-out and broken lamps is a common practice. Apart from direct contact from broken lamps, a possible long-term environmental and health risk of this careless disposal practices in the studied area is that, in the absence of appropriate disposal mechanisms, accumulated mercury waste could penetrate and pollute the groundwater system. This is considered an environment and potential health risk because it is observed that majority

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<sup>83</sup> Retrieved from: <https://www.epa.gov/cfl/what-are-connections-between-mercury-and-cfls> (Last accessed on: 01.05.2019).



of households in the case study area depend solely on personal bore-holes for domestic water supply. The anticipated widespread adoption of CFLs in the case study area underscores the need for the establishment of appropriate disposal mechanisms for burned-out CFLs as an early mitigation action and also, since CFLs are relatively new technology in the region, end-users may not be quite aware of the mercury content in CFL light bulbs and as a result, may not take necessary precautions when handling broken CFL light bulbs or may not see the need for appropriate disposal of burned-out lamps. Awareness creation on the possible health risks of mercury and the need for proper precautions when handling broken bulbs, in this case, is quite essential.

## **8. ENERGY EFFICIENCY POLICY ASSESSMENT – THE NIGERIA NATIONAL ENERGY EFFICIENCY ACTION PLAN (NEEAP)**

### **8.1 INTRODUCTION TO CHAPTER EIGHT**

The objective of creating a sustainable and stable energy supply is the focal point of the Nigerian energy and climate policies. This objective is built on the global sustainable energy for all (SEforAll) target of doubling the rate of improvement in energy efficiency. Also, based on this global SEforAll target, the Economic Community of West African States (ECOWAS) Commission aims to improve access to clean and affordable energy in the region.<sup>84</sup> The Nigerian government is recognizing energy efficiency as an energy resource and is adopting a three-pillar model to champion energy savings; increasing supply-side efficiency (such as enhancing efficiency of grid infrastructures to reduce transmission losses), improving economy-wide efficient use of energy (especially in the three main energy consuming sectors – residential, industries, transport) and building enabling structures and measures to support these actions (FMP, 2015, p. 26). There is a proposed aim of realizing the replacement of 40 % of old and inefficient appliances with energy-efficient products by 2020 and to sustain energy efficiency best practices beyond 2030 (FMP, 2015, p. 37). As part of its effort towards achieving an energy efficient market transformation, the government is focusing on improving the efficiency of the three major electricity consuming electrical products namely; light bulbs, refrigerators and air conditioners

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<sup>84</sup> Based on information from ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) official website, 80 % of the population in the ECOWAS region lack access to modern, clean and affordable energy, thereby relying on biomass energy to meet basic household energy needs (ECREEE official website). Available online at: <http://www.ecreee.org/project/climate-change> (Last accessed on: 02.05.2019).

(ECN, 2013a, p. 2). Efforts at increasing the market share of efficient appliances necessitated the development of the National Energy Efficiency Action Plan (NEEAP). The NEEAP was developed as a sequel to the National Renewable Energy and Energy Efficiency Policy (NREEEP). The NREEEP is a summary of the government's statement of intent to enhance the optimal utilization of the nation's energy resources for sustainable development. The NREEEP advocates cross-cutting measures to drive the improvement of energy efficiency such as actions to promote the adoption of energy saving appliances and devices and the need for the government to play a leading role in championing energy efficiency. The NEEAP sets out key policy instruments to achieve the government's aim of promoting the adoption of energy saving appliances as established in the NREEEP.

This chapter provides a detailed assessment of the instruments employed to promote the MEPS program in Nigeria. The assessment is based on internationally established best standards (the integrated policy framework), which has been adapted in a regional context by the ECOWAS Commission to advance appliance energy efficiency in the ECOWAS region. The chapter evaluates the status of appliance energy efficiency policies in Nigeria to identify its conformity to international and/or regional best practices and also, to identify possible areas of improvement in order to create a favorable condition for effective energy efficiency deployment in Nigeria. The assessment conducted in this chapter is aimed at achieving objectives four and five of this research.

## **8.2 BACKGROUND**

Pursuant to Article 43 of the ECOWAS Energy Protocol on energy efficiency (see section 8.3.1) and the mandates of ECOWAS Energy Efficiency Policy (EEEP) (section 8.3.2), the federal government of Nigeria, through the inter-ministerial committee on renewable energy and energy efficiency (ICREEE), headed by the federal ministry of power (FMP), developed the National Energy Efficiency Action Plan (NEEAP)<sup>85</sup> which was adopted by ICREEE and approved by the National Council on Power (NACOP) on 14 July, 2016 (FMP, 2016, p. 1). The NEEAP serves as the major energy efficiency policy document that enumerates measures, policies, laws and planned actions to be implemented at the national level in order to champion energy efficiency

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<sup>85</sup>The NEEAP sets out instruments through which the Nigerian government plans to achieve its national energy efficiency targets in key energy consuming sectors.

in the country. The approved NEEAP estimates to increase efficient energy use in high energy consuming sectors (residential, industrial and transport) by at least 20 % by 2020 and 50 % by 2030 (FMP, 2016, p. 10). In respect to appliance use, the NEEAP estimated a 40 % replacement of inefficient light bulbs and other old and inefficient appliances with energy-efficient types by 2020 and targets almost a 100 % replacement of inefficient light bulbs by 2030 (FMP, 2016, p. 10). In line with the NREEEP, the NEEAP also emphasized on the achievement of established energy and climate goals. The goals are based on envisaged reduction in economy-wide energy demand and emissions by significantly increasing energy efficiency. The energy and climate goals are summarized as follows (FMP, 2015; FMP, 2016):

- 40 % reduction in economy-wide energy consumption by 2030 compared to the base year of 2015.
- 15 % reduction in energy-related greenhouse gas (GHG) emissions by 2025 compared to the reference year of 2013.

By establishing these goals, the federal government has set the bar against which the implementation of its economy-wide energy efficiency improvements can be measured in the future. In this research, the assessment of the NEEAP in delivering its established targets is based on the conceptual considerations, “assessment can be performed in respect to the degree to which a specific program or policy empirically meets or does not meet a particular standard or norm” (Fischer, 1995) (see chapter 2).

### **8.3 EVOLUTION OF ENERGY EFFICIENCY POLICIES IN A REGIONAL CONTEXT**

In the regional context, there have been several activities of ECOWAS on advancing energy efficiency. ECOWAS was established on 28 May, 1975 through the Treaty of Lagos.<sup>86</sup> ECOWAS consists of fifteen (15) member regional nations<sup>87</sup> with a mandate to promote economic integration in all sectors of activity of the member states (ECOWAS Treaty, 2016).

In recognition of established global ex-post impacts of energy efficiency, the ECOWAS Commission embarked on efforts to introduce energy efficiency in the region. It is expected that energy efficiency would assist in addressing the vast energy challenges in the region, such as

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<sup>86</sup>The treaty of Lagos which was a multilateral agreement signed by the Heads of States and Governments of member states on 28 May, 1975, provided the mandate for the establishment of the ECOWAS regional body (ECOWAS Treaty, 2016).

<sup>87</sup>ECOWAS member nations are: Republic of Benin, Burkina Faso, Cape Verde, Cote D' Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Sierra Leone, Senegal and Togo (ECOWAS Treaty, 2016).

poor accessibility and reliability of electricity supply.<sup>88</sup> Furthermore, the ECOWAS Commission asserts that energy efficiency would assist in the regional mitigation efforts towards the fight against climate change.<sup>89</sup> Improved electricity access and reliability of supply with less environmental emissions constitute parts of the ECOWAS Commission's millennium development goals (MDGs). The ECOWAS Heads of State during the 26<sup>th</sup> session of the Authorities of Heads of State and Government on 31 January, 2003 in Dakar, Senegal, adopted the ECOWAS Energy Protocol and introduced Article 43 on energy efficiency (A/P4/1/03). The ECOWAS Energy Protocol serves as an addendum to the ECOWAS Treaty and the introduction of Article 43 into the ECOWAS Energy Protocol provided a legal structure to promote long-term regional co-operation for the advancement of energy efficiency in ECOWAS member states (A/P4/1/03). Consequently, the need to create an ECOWAS special unit for energy efficiency emanated and during the 61<sup>st</sup> session of the ECOWAS Council of ministers on November 28, 2008 in Ouagadougou, Burkina Faso, regulation C/REG.23/11/08 that gave the mandate for the establishment of the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE) was adopted (ECREEE, 2013, p. 6). The ECREEE secretariat was inaugurated on 6 July, 2010 in Praia, Cape Verde. The main vision of ECREEE is to improve the security of energy supply and increase access to modern energy services through the widespread adoption of energy efficiency and renewable energy in the region. ECREEE also aims to support the region's economic and social development in an environmentally friendly way.

### **8.3.1 ARTICLE 43 OF THE ECOWAS ENERGY PROTOCOL**

The Contracting Parties of the ECOWAS Energy Protocol, wanting to guarantee a secured regional efficient and reliable supply of electricity and other forms of energy and to successfully remove technical, institutional and other related barriers to energy-efficient equipment and technologies and also, recognizing the importance of efficient use of energy and sustainable development, adopted the ECOWAS Energy Protocol, as amended, with the introduction of Article 43 to the Protocol on 31 January, 2003 in Dakar, Senegal. The general aim of the Protocol is to create a legal framework that will establish long-term regional co-operation in the energy

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<sup>88</sup> 126 million people out of the total population of 334.6 million people in the ECOWAS region lack access to electricity services (ECREEE official website).

<sup>89</sup> Based on information from ECREEE official website, change in precipitation levels and weather patterns as a result of climate change, will cause more intense droughts and storms in the region which will adversely impact on other sectors like energy, health, trade and the transport sectors (ECREEE official website).

sector, which would be mutually beneficial to Contracting Parties through advancing investment in the energy sector, thereby, increasing energy trade in the West Africa sub-region. The relevance of the Article cannot be over-emphasized, however, in consideration to this dissertation; relevant sections of the Article are enumerated below:

- Article 43 (1) (b): “Contracting Parties shall establish energy efficiency policies and appropriate legal and regulatory framework which promote, inter alia:
  - i. reduction of barriers to energy efficiency to enhance investment
  - ii. mechanisms to finance energy efficiency initiatives
  - iii. education and awareness creation
  - iv. transparency of legal and regulatory frameworks.
- Article 43 (1) (g): “Co-operative or coordinated action shall take into account relevant principles adopted in international agreements, aimed at protection and improvement of the environment, to which Contracting Parties are Parties.”
- Article 43 (3) (b): “Contracting Parties shall develop, implement and regularly update energy efficiency programs best suited to its circumstances; which may include the following activities:
  - i. development of long-term energy demand and supply scenarios to guide decision making.
  - ii. assessment of the energy, environmental and economic impacts of actions taken to guide policy designs.
  - iii. establishment of standards designed to improve the energy efficiency of energy consuming technologies and efforts to harmonize these standards internationally to avoid trade limitations.
  - iv. promotion of the use of the most energy-efficient equipment that are cost-effective and environmentally friendly.
  - v. establishment of specialized energy efficiency bodies at appropriate levels, that are sufficiently funded and staffed to develop and implement policies.
- Article 43 (4): “Role of ECOWAS executive secretariat – The ECOWAS executive secretariat shall endeavor to adopt within 180 days after entry into force of the Protocol,

procedures for keeping under review and facilitating the implementation of its provisions, including reporting requirements.”

The above enumerated sections highlight parts of Article 43 of the ECOWAS Energy Protocol considered relevant to this dissertation because they highlight the several regional commitments that bind Nigeria on advancing energy efficiency.

### **8.3.2 ECOWAS ENERGY EFFICIENCY POLICY**

Pursuant to Article 43 (4) and Article 43 (3) (b) respectively of the ECOWAS Energy Protocol, ECREEE developed the ECOWAS Energy Efficiency Policy (EEEP) in 2012 and as well, urged member states to establish energy efficiency focal institutions for the ease of regional coordination and collaboration in energy efficiency activities. ECREEE established a target to double the annual regional improvement in energy efficiency and the phasing out of inefficient incandescent lamps by 2020 as stipulated in the EEEP (ECREEE, 2013, p. 15). As a result, member states were mandated to develop action plans with support from ECREEE to ensure the smooth take-off of energy efficiency deployment in the region and to ensure the realization of these targets. ECREEE advocates an integrated policy framework and implementation strategies to ensure an effective transition to efficient technologies in all ECOWAS countries.

In reference to the ECOWAS Energy Efficiency Policy in NEEAP, an effective set of national actions targeting improvements in appliance energy efficiency and widespread diffusion of energy-efficient technologies must cover the four components of the integrated policy approach (FMP, 2016, p. 53):

- Minimum energy performance standards (MEPS)
- Supporting policies and mechanisms (SPM)
- Monitoring, verification and enforcement (MVE)
- Environmentally sound management systems (EnSM)

These four integrated policy components were disaggregated to address policy issues that cover the three major electricity consuming equipment in the region (lighting, refrigerators and air conditioners).

### **8.4 ECOWAS INTEGRATED POLICY FRAMEWORK**

ECOWAS stipulated key activities for minimum energy performance standards:

- Member states are mandated to develop MEPS for efficient lamps, refrigerators and air conditioners (the major energy consuming appliances in the region) through adequate baseline market research and other stakeholder consultation.
- Member states are mandated to develop MEPS based on internationally established best practices.
- Member states are mandated to pursue and adopt ECOWAS harmonized MEPS.

For instance, the ECOWAS MEPS for lighting products (which currently covers only CFLs) requires that energy-efficient lamps that are manufactured and/or imported into the region meet the following key requirements:

**Lamp efficacy:** Lamps must have a minimum lamp efficacy<sup>90</sup> of the following specifications as illustrated in table 8.1

Table 8.1 ECOWAS mandatory specifications for CFL lamp efficacy

Lamp Power (LP) Wattage (W)	Minimum efficacy (lumens/Watt - lm/W)
LP < 5	40
5 ≤ LP < 9	45
9 ≤ LP < 15	50
15 ≤ LP < 25	55
LP ≥ 25	60

Source: Nigerian National Energy Efficiency Action Plan (FMP, 2016, p. 54)

**Lamp lifetime:** CFLs must have a minimum rated life of not less than 6000 hours and should be able to operate within a voltage range of 160 to 260 Volts (V). International best practice typical efficacy for CFL light bulbs ranges from 50-70 lm/W and standard CFL bulb lifetime should be between 6,000-15,000 hours (U4E policy guide series, 2017a, p. 21).

**Mercury content:** Lamps mercury content must not exceed 2.5mg.

ECOWAS stipulated key activities for supporting policies and measures

- Develop and adopt measures for awareness campaign targeting end-users, policy makers and relevant stakeholders; the focus should be on the benefits of energy-efficient

<sup>90</sup> According to UN Environment – Global Environment Facility (GEF), lamp efficacy is defined as a measure of how well a lamp produces visible light and it is measured in lumens per Watt (lm/W) (UN Environment, 2013).

technologies over the conventional products. The awareness program should be performed through radio, television, public forum such as community centers.

- Free distribution of CFLs to selected residential areas.
- Implementation of financing schemes that can cover or reduce the initial investment cost of efficient products.
- Adopting a harmonized mandatory labeling and certification for efficient lamps.

ECOWAS stipulated key activities for monitoring, verification and enforcement

- Create national inventories for lighting products
- Monitor importation of appliances at airports and seaports within ECOWAS countries.
- Establish internationally accredited regional test facilities for product testing which should be based on the International Electrotechnical Commission (IEC) test standards.
- Assist in the establishment of test facilities at national levels and/or build capacity to any existing national testing center and ensure test facilities meet international and regional standards.
- Set penalties for non-compliance to established standards and ensure that manufacturers, importers, wholesalers, retailers, distributors, end-users of efficient products have a clear understanding of penalties for non-compliance to stipulated requirements for standards and labeling.

ECOWAS stipulated key activities for environmentally sound management

- Ensure public awareness for the need to embark on environmentally sound disposal of used products, especially CFLs.
- Establish and adopt national regulation for environmentally sound disposal of end-of-life products.
- Create national collection centers or measures for end-of-life efficient lamps
- Install recycling and disposal facilities for efficient lamps and other appliances.

The above enumerated policy strategies are ECOWAS best practice approach, adapted from the UN integrated policy framework, to ensure an effective transition to energy-efficient appliance market in all ECOWAS countries and to put in place a strong institutional framework foundation to support the regional effort towards an efficient economic development. These policy



measures have been designed to be implemented in all member states through relevant national government agencies and departments with regional support from ECREEE. It was expected that regional-wide standards and labels for major energy equipment would be developed by the end of 2014 and member states should create instruments for financing sustainable energy by the end of 2013 (ECREEE, 2013). Interview response from the key informant at the SON shows that the ECOWAS regional standard harmonization for lighting, refrigerator and air conditioner have only been completed recently, but the domestication process (including stakeholder consultation) is still ongoing in Nigeria (as at the time of this study) and thereafter, the approval by the National Standards Council is expected later in the year (2019). Also, the assessment of the NEEAP shows that Economic instruments such as financial incentives, to support the uptake of energy-efficient appliances, are still in their planning stages.

## **8.5 ASSESSMENT OF THE NEEAP**

### **8.5.1 MINIMUM ENERGY PERFORMANCE STANDARD**

The NEEAP adopts the integrated policy framework for an effective energy-efficient market transition in the country. Efforts were made in the NEEAP to develop policy measures that cover the four components of the integrated policy framework. These efforts exhibit ambitious attempts to encourage the diffusion of efficient appliances in the country. Pursuant to Article 43 (3b) iii and iv, and also, in commitment to the ECOWAS regional policy that mandates member states to develop MEPS for major energy consuming equipment, MEPS for lighting – Nigerian Industrial Standard (NIS 747:2012) was approved by the National Committee on electrical appliance (SON, 2010, p. 2). The United Nations Development Program (UNDP) and SON partnered to develop the MEPS for lighting which is already being enforced. Reports from SON show that the MEPS currently covers only compact fluorescent lamps (CFLs) (self-ballasted lamps<sup>91</sup>) with a rated wattage up to 60 watts (W) that are intended for domestic and similar general lighting purposes (SON, 2010, p. 6). Table 8.2 shows that the lamp performance standards (lamp efficacy) requirements in the developed MEPS for lighting are relatively in accordance with international and ECOWAS regional standards.

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<sup>91</sup>Self-ballasted CFL lamps have integrated means (ballasts) that controls incoming current which ensures proper voltage for a stable operation of the light source (SON, 2010, p. 6)

Table 8. 2 Comparison of lamp efficacy with regional standards

Lamp Power (LP) in watts (W)	National standard (minimum efficacy in lm/W)	ECOWAS regional standard (minimum efficacy in lm/W)
LP < 5	≥ 40	40
5 ≤ LP < 9	≥ 40	45
9 ≤ LP < 15	≥ 48	50
15 ≤ LP < 25	≥ 50	55
LP ≥ 25	≥ 55	60

A national minimum bulb lifetime of 6000 hours for CFLs (SON, 2010, p. 10) is also in conformity with the 2 regional and international standards.

The MEPS for air-conditioners<sup>92</sup> and refrigerators<sup>93</sup> were recently completed by the Technical Committee on Refrigeration and air conditioning of SON and approved by the Nigeria Standards Council in August 2016 but not yet implemented. Initially, a roadmap was designed by SON and other relevant stakeholders for the implementation of the MEPS for refrigerators and air conditioners. It was expected that enforcement will commence after 18 months from the launch date for local manufacturers. This is to allow old stocks to be exhausted. Importers of completely built units are to fully comply within six months from the launch date. However, it was reported during an interview session with Mr. Uyigue, the Project Manager, Global Environment Facility (GEF) – United Nations Development Programme (UNDP) Nigeria Energy Efficiency Programme, in Abuja (28 September, 2017), that importers of these appliances are requesting for more time to enable them to adjust their businesses to meet the established standard. Recent inquiries from SON to confirm the current implementation status of the MEPS for refrigerators and air conditioners show that implementation is also being delayed due to the ongoing domestication process of the regional standard. The EEEP did not specify the details for regional MEPS for refrigerators and air conditioners. However, it seems the harmonized regional

<sup>92</sup>The MEPS for air conditioners presents minimum energy performance standards for air conditioning systems imported or manufactured in Nigeria with cooling power output up to 20 kW (commonly rated cooling capacity output for residential units is ≤ 10 kW and rated cooling capacity output for commercial units is between 10 – 20 kW); the MEPS does not cover air conditioning systems that also have heating function (SON, 2013a, p. 4). Air conditioning systems of the following types are covered: portable, unitary, split, centralized systems and multi split (SON, 2013a, p. 4).

<sup>93</sup>The MEPS for refrigerators specifies minimum standard requirements for household refrigerators that are manufactured or imported into Nigeria and of the following types: refrigerators with freezer, refrigerators without freezer and refrigerators with ice dispenser (SON, 2013b, p. 4).

MEPS for air conditioners and refrigerators are adapted to MEPS in the countries within the region (such as Nigeria and Ghana) that have developed standards for these appliances. For instance, SON has confirmed that the regional standard for air conditioners, just like the Nigerian MEPS for air conditioner, allow only air conditioners with a minimum energy performance of 2.8 EER into the region. The MEPS for refrigerators and air conditioners in Nigeria is communicated through the mandatory Nigerian Energy Guide Label/Star rating.<sup>94</sup> The label, when implemented, informs the consumer the amount of electricity the product will consume per month (expressed in kWh/month) and the star rating gives an insight of the corresponding MEPS category. For air conditioners, the Energy Guide Label/star rating is aligned to the MEPS based on the energy efficiency ratio (EER) of the appliance. As shown in table 8.3, the air conditioner regulation defines a labeling scheme from one to five stars, with a mandated minimum energy performance level of 2.8 EER for one star and 5.00 EER for five stars.

Table 8.3 MEPS for AC in Nigeria categorized based on EER for each energy class and star rating (Source: SON, 2013a, p. 10)

Type of AC	Energy class and Star rating	MEPS value based on EER
All AC with cooling capacity up to 20 kW	5-star	$EER \geq 5.00$
	4-star	$4.20 \leq EER < 5.00$
	3-star	$3.60 \leq EER < 4.20$
	2-star	$3.20 \leq EER < 3.60$
	1-star	$2.80 \leq EER < 3.20$

The developed standard simply means that all air conditioners manufactured or imported into Nigeria must have a minimum EER value of  $\geq 2.8$ . As discussed in section 5.4.2 of this dissertation, the national and/or regional minimum energy standard of 2.8 EER for air conditioners may not be quite ambitious especially when compared to minimum energy performance requirements for air conditioners in countries considered as major appliance

<sup>94</sup>The Nigerian Energy Guide Label is a comparative label that helps consumers know the efficiency of the product in the market, the energy efficiency level or MEPS value is defined by the number or star rating on the label. The Nigerian Energy Guide Label has five (1 to 5) energy classes that correspond to different energy efficiency levels; a higher number signifies higher efficiency levels. The label should be placed on the body and packages of products (SON, 2013a, p. 8).

trading partners such as China, Japan, and Korea<sup>95</sup> (see table 5.9). This means that more efficient products can be introduced into the Nigerian and/or regional markets if regulations stimulate their supply. It is likely that if current standards are not reviewed to mandate the supply of more efficient products, further efficiency gains will be slow to achieve which may limit the rate of compliance to pledges reached in Nigeria’s NDC.

For refrigerators, the Energy Guide Label/star rating is aligned to the MEPS based on the energy efficiency index (EEI)<sup>96</sup> of the appliance (table 8.4). Also, just as in the case of the air conditioner, the EEI determines the star rating of the refrigerator which in turn, indicates its energy efficiency level. The EEI is measured based on two different climate classes,<sup>97</sup> the sub-tropical (ST) climate class and the tropical (T) climate class.

Table 8.4 MEPS for refrigerators in Nigeria categorized based on EEI for each energy class and star rating (Source: SON, 2013b, p. 5)

<b>EEI for ST climate class and corresponding star rating</b>	<b>EEI for T climate class and corresponding star rating</b>
75 – 90 (1 star)	90 – 100 (1 star)
55 – 75 (2 star)	75 – 90 (2 star)
42 – 55 (3 star)	55 – 75 (3 star)
30 – 42 (4 star)	42 – 55 (4 star)
< 30 (5 star)	< 42 (5 star)

### 8.5.2 NEEAP – SUPPORTING POLICY MEASURES

The NEEAP enumerates quite ambitious complementary measures to support the MEPS program and to ensure effective energy-efficient market transformation. The assessment of the

<sup>95</sup> A recent study by CLASP highlights that Chinese, Japanese and Korean brands dominate the appliance market in Nigeria, accounting for over 70 % of all models (CLASP, 2018, p. 25).

<sup>96</sup>The EEI expresses the annual electricity consumption relative to a reference consumption that is based on the storage volume and the type of the refrigerator (e.g. without freezer or with freezer) (SON, 2013b, p. 5).

<sup>97</sup>The climate class of the refrigerator is the range of room temperatures the appliance is designed to function; it guarantees that the appliance will function properly as the temperature changes (within the specified temperature range for a particular climate class) in the environment in which the refrigerator is located (SON, 2013b, p. 9). The appliance can be used only in the specified temperature ranges for a particular climate class as illustrated: Sub-normal (SN) from +10°C to +32°C; Normal (N) from +16°C to +32°C; sub-tropical (ST) from +18°C to +38°C; and tropical (T) from +18°C to +43°C (SON, 2013b, p. 10). The temperature classification for each climate class is determined by the IEC. Only refrigerators that can operate in the ST and T climate class are allowed in Nigeria (SON, 2013b, p. 7).

NEEAP shows that supporting policy instruments that comprise a combination of economic, market, information and financial measures are either planned or implemented.

The NEEAP reveals that Nigeria has adopted some measures for information dissemination and to create awareness, especially for efficient lighting products. These measures range from completed pilot projects that involve the bulk procurement and free distribution<sup>98</sup> of CFLs in selected residential areas to create awareness for energy-efficient lighting products in households, the United Nations Development Programme (UNDP) awareness and training program for marketers and retailers, the mandatory comparative energy guide labels for lighting products and a planned phase-out of incandescent light bulbs (FMP, 2016). For information dissemination, the NEEAP also mandates all lamps to have the following information printed on the individual package of each lamp: the lifetime of the lamp in hours, rated wattage of the CFL light bulb showing a comparison of the corresponding incandescent lamp which equivalence is claimed.

The observed energy efficiency supporting policies for refrigerators and air conditioners are predominantly, the development of the comparative energy guide labels and regulatory measures such as the control on the importation of old and used refrigerators and air conditioners. The supporting policy measure mandates that the developed labels for electrical appliances should be on the body and packages of these electrical products and should clearly and consistently provide the following information about the product: for refrigerators; climate class which must be ST or T, MEPS value, noise level, volume in liters (l). The energy guide label must also indicate the energy consumption of the appliance in kWh/month and the corresponding star rating (SON, 2013b, p. 7). Similar requirements are also mandated for air conditioners.

Conveying information to end-users through campaigns is also in conformity with the recommendations of the integrated policy approach since information dissemination will enhance end-users' knowledge, appreciation and acceptance of efficient electrical products. The NEEAP reports that awareness raising campaigns to inform consumers and other

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<sup>98</sup>The bulk procurement and distribution of CFLs in selected residential homes in Nigeria was a project initiated by the Energy Commission of Nigeria (ECN), the Cuban Government and the ECOWAS Commission (ECN, 2010, p. 2). The project involved the distribution of 1 million CFLs in selected residential homes in six states in Nigeria. The basis for the selection of households was buildings that have pre-paid meters and/or buildings with installed central metering systems (ECN, 2010, p. 5). The impact analysis of this project (replacement of 1 million incandescent lamps with CFLs) shows an average monthly electricity savings of 3,196,886.4 kWh (ECN, 2010, p. 38).

stakeholders such as energy suppliers and retailers of the social, economic and health benefits of efficient lighting are ongoing (FMP, 2016, p. 16). Implementation time frame to conduct public awareness campaigns was scheduled to commence in 2015 through 2020 and the Federal Ministry of Environment and the Federal Ministry of Power have been charged with the program implementation (FMP, 2016, p. 17). Information dissemination is very imperative in selling efficiency and the need to devise a context-specific means of informing end-users is very necessary.

The review of the NEEAP shows that innovative financial instruments to support the advancement of the MEPS program are mainly in their planning stages. The planned financial instruments/incentives reported in the NEEAP are customer credit schemes, on-bill financing to overcome the burden of high initial investment costs and enhance the purchase of energy-efficient products and import tax credits to reduce importation duties of energy-efficient appliances (FMP, 2016, p. 25).

### **8.5.3 NEEAP – MONITORING, VERIFICATION AND ENFORCEMENT**

Monitoring, verification and enforcement (MVE) is an essential component of the integrated policy framework. The NEEAP highlights MVE instruments to ensure appliances manufactured or imported into the country meets the established standards. Robust MVE instruments are very fundamental to realizing a successful policy-driven market transformation outcome. Verification measures as reported during an interview session with the Head of Electrical-Electronics laboratory at the Standard Organisation of Nigeria (SON), Mr. Richard Adewunmi in Lagos (19.12.2016) reveals that SON adopts international best practice test methods recommended in the integrated policy framework in ascertaining appliance performance requirements. As recommended in the integrated policy approach, test procedures adopted by SON to verify lighting standards have been aligned with the IEC test procedures; particularly the IEC 60081:1984 and the IEC 60968:1988 (SON, 2010, p. 6).<sup>99</sup> For refrigerators, the verification test to determine the EEI has also been aligned with the test procedures of IEC 62552-2:2015<sup>100</sup> (SON, 2013b, p. 4); and for air conditioners, test for compliance to the established standard is

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<sup>99</sup> The IEC 60081 and IEC 60968 covers test procedures for general lighting services for tubular fluorescent lamps and self-ballasted lamps, respectively (SON, 2010, p. 6).

<sup>100</sup> The IEC 62552-2:2015 covers test methods for performance requirements for household refrigerating appliances (SON, 2013b, p. 4).

performed in accordance to applicable IEC and International Organization for Standardization (ISO) test procedures. The quoted verification tests for air conditioners include the IEC 60335-2-40 and the ISO 5151 (SON, 2013a, p. 4).<sup>101</sup> For instance, the IEC 62552 allows measurement of energy consumption of refrigerators at 16°C and 32°C which will ensure that products are tested for energy consumption in a manner closer to their normal use in homes where the temperature is generally close to 16°C (Commonwealth of Australia, Department of the Environment and Energy, 2017, p. 21). Requirements to test for the energy consumption of refrigerator-freezers at different temperatures from that of the IEC would have meant that products imported into the country would be subjected to a unique national test procedure to assess whether appliances meet MEPS. The test procedures are institutionalized in Nigeria through the mandatory SON Conformity Assessment Programme (SONCAP)<sup>102</sup> for electrical products imported into Nigeria and the Mandatory Conformity Assessment Programme (MANCAP)<sup>103</sup> for locally manufactured electrical products. Appliance testing is carried out at SON's designated testing laboratories in Lagos, Nigeria. Monitoring measures reported include periodic checks of appliances in the market and warehouses of importers. These periodic checks are conducted unannounced to increase the probability of identifying cases of non-compliance. Enforcement is reportedly performed through seizure and destruction of identified sub-standard products and defaulters are meant to bear the cost of such destructions and also pay respective fines. Mr. Adewumi also explained that, after verification test, Energy Guide Labels that does not reflect the actual efficiency level of a particular electrical product will be changed to convey the real energy efficiency level of that particular product.

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<sup>101</sup> The IEC 60335-2-40 covers air conditioner safety requirements and the ISO 5151 covers methods for testing and performance rating for non-ducted air conditioners and heat pumps (SON, 2013a, p. 4).

<sup>102</sup>The SONCAP is an assessment carried out on appliances before they could be imported into Nigeria. The assessment is performed to ensure products are compliant with Nigerian standards and to confirm the energy consumption that is provided on the product's label. Screened products are issued with SONCAP Certificate (SC) which should be presented before the products are cleared from any Nigerian port. The verification test method is based on appropriate methods recommended by the IEC and the ISO (Retrieved from the response from the research interview with Mr. Richard Adewumi, 19.12.2016, Lagos, Nigeria).

<sup>103</sup>The MANCAP is a mandatory product certification scheme implemented by SON in 2006. This standard ensures that all products manufactured in Nigeria meet the minimum Nigerian Industrial Standards (NIS) before they could be sold in Nigeria or exported outside the country. The test procedures adopted for MANCAP is also based on recommended methods by relevant international organizations, the IEC and ISO (Retrieved from the response from the research interview with Mr. Richard Adewumi, 19.12.2016, Lagos, Nigeria)

#### **8.5.4 NEEAP – ENVIRONMENTALLY SOUND MANAGEMENT**

In line with recommended international best standards and the ECOWAS stipulated key activities for environmentally sound management (EnSM), the planned measures in Nigeria as enumerated in the NEEAP range from creation of awareness among end-users, manufacturers, importers on the need for environmentally friendly disposal of burned-out light bulbs and also, establishment of collection systems for used lamps. In respect to this, implementation strategies have been designed to ensure environmentally sound management of end-of-life products. The Extended Producer's Responsibility (EPR) program initiative requires importers, producers, distributors of products to take adequate responsibility for life cycle management of their products by providing avenues to take back their products at their end-of-life. Based on the questionnaire response from NESREA, this program is currently ongoing. EnSM measures will ensure that the use and disposal of energy-efficient products do not constitute any harm to the environment.

The ECOWAS Energy Efficiency Policy recommends that CFL bulbs in the region must have a mercury-content level of not more than 2.5 milligrams (mg) per bulb (FMP, 2016, p. 54).<sup>104</sup> The NEEAP did not specify a particular national tolerated mercury content level in CFL light bulbs manufactured or imported into Nigeria but based on questionnaire response from the Standards Organisation of Nigeria (SON), the allowed mercury content in CFL lamps in Nigeria is 5 mg and there are plans by the agency to revise this standard to 3 mg. The federal ministry of environment (FME) through NESREA is directly responsible for the verification of mercury content levels in CFLs; however, based on questionnaire response from the FME, it is understood that measures to conduct the verification of mercury content levels in CFLs are not yet established and still in their planning stages. Also, reasons for the variations in allowed mercury content levels with the regional standard were not provided. This constitutes possible contradictions with established regional mandate. If not properly managed, mercury could pose a potential health risk in the case study area of Enugu. As earlier stated, several homes depend on individual bore-holes for water supply both for drinking and other domestic activities. Mercury can penetrate and accumulate in the ground which may pollute the groundwater

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<sup>104</sup>Report from the European Commission's (EC) Scientific Committee on Health and Environmental Risks (SCHER) reveals that presently, it may not be technically possible to produce mercury-free CFLs, however, international best standard is progressively aiming for lower levels of mercury in CFLs (SCHER, 2010, p. 5).



system, making it unsafe for human consumption. The technology for the recycling of mercury is already available globally (U4E policy guide series, 2017a, p. 69).

EnSM measures for refrigerators and air conditioners were not addressed in the NEEAP. However, as a Party to the Montreal Protocol, Nigeria has established the National Ozone Office (NOO) which is responsible for the domestication of the mandates reached in the Protocol. Part of the domestication process (as discussed in chapter 7 of this dissertation) involves the control of the importation and use of items containing ozone-depleting substances, which includes old and used refrigerators and air conditioners (National Ozone Office website). In reference to the NEEAP, EnSM measures for refrigerators and air conditioners are mainly in their planning stages.

## **8.6 CHAPTER DISCUSSION**

The assessment of the NEEAP shows that the integrated policy framework was adopted as the policy approach for advancing appliance energy efficiency in Nigeria. Each component of the integrated policy framework has been taken into consideration in designing policy instruments for the advancement of end-use energy efficiency.

### **8.6.1 ANALYSIS OF THE MEPS AND SUPPORTING POLICIES**

The review of the SON's technical documents on MEPS in Nigeria shows that basic performance requirement for CFL lamps (such as the lifetime of light bulbs and lamp minimum efficacy levels) meet regional and international recommended standards. The document also indicates that the development of test procedures for air conditioners and refrigerators were also based on international best practices as recommended by the IEC and the ISO (SON, 2013a; SON, 2013b). For instance, the MEPS for air conditioner references the International Standard for “Non-ducted air conditioners and heat pumps – testing and rating for performance (ISO 5151)” issued by the International Organization for Standardization (ISO) which was adopted by SON Technical Committee on Refrigeration and Air conditioning (SON, 2013a, p. 4).

It is expected that harmonized standards for refrigerators and air conditioners within the ECOWAS region will be domesticated in the ECOWAS member states. A harmonized regional standard, among other benefits, will promote a regional market for energy-efficient technologies, creating economies of scale that will attract investments into the regional production of energy-efficient equipment both at cities and national levels.

Lack of adequate information on product packages was generally observed especially for CFL light bulbs. Relevant information (such as CFL wattage in comparison to that of incandescent for which equivalent is claimed – figure 8.1) was not observed on various brands of CFL light bulbs in the case study area.



Figure 8.1 Comparison of labelling information (Source: Photo produced by the author)

The picture on the left shows that a 9.5 W LED light bulb will provide the same light output as a 60 W incandescent light bulb. Such information will enable end-users to make easy and quick choice for an appropriate replacement of their incandescent light bulbs. This vital information (which is mandated in the NEEAP as a requirement on lighting packages) is not observed or provided on the product package of CFL light bulbs in the case study area as shown in the picture on the right which was taken in a retail store in Enugu.

The assessment of the NEEAP shows that financial incentive measures are still in their planning stages. Energy-efficient products are relatively more expensive than inefficient types. Table 8.5 is the observed retail prices of CFL light bulbs and incandescent light bulbs in the case study. The table shows that CFL and LED light bulbs are more expensive than the incandescent bulb by almost a factor of 12 and 23 respectively.

Table 8.5 Wattage and price range of incandescent, CFL and LED bulbs in the case study

Incandescent bulbs	Wattage available	40 W, 60 W, 100 W, 200 W
	Price range	NGN 30 – NGN 100 (US\$ cents 0.09 – 0.29)
CFLs	Wattage available	15 W, 20 W, 26 W, 40 W, 60 W
	Price range	NGN 350 – NGN 1100 (US\$ 1.00 – 3.14)
LEDs	Wattage available	3 W, 5 W, 8 W, 15 W
	Price range	NGN 700 – NGN 2385 (US\$ 2.30 – 7.78)
Total population	3267837	
Poverty count	1241778	
Percentage poverty level	38.00%	

International poverty line: US\$ 1.90/day (ESG, 2016); US\$ 1 = Nigeria Naira (NGN) 306.5 (CBN official website, 2018).

The result from the survey underscores the need to design and implement financial instruments that would enable consumers to overcome the burden of high initial investment costs of energy-efficient appliances. 55 % of the respondents consider appliance initial cost as a significant factor when choosing an appliance to purchase (figure 5.6, section 5.2). This means that this group of people would most likely prefer cheaper alternatives to efficient products and may only consider efficient types if prices are considered favorable. Besides, considering the analysis presented in section 7.4.1 of this dissertation, consumers may likely not voluntarily give away their old and inefficient refrigerators without a form of measure that provides financial assistance from the government.

### **8.6.2 ANALYSIS OF MONITORING, VERIFICATION AND ENFORCEMENT**

Monitoring, verification and enforcement (MVE) procedures ensure that products supplied in the Nigerian market are safe, reliable and consistently perform the way that suppliers claim. Based on the assessment conducted, MVE instruments for end-use energy efficiency have been designed and implemented. The SONCAP and MANCAP mandatory programs ensure that products or appliances are subjected to a test process to verify the energy consumption that is claimed on the products. Products that do not meet the specified regulations cannot be supplied into the Nigerian market. Furthermore, as a predominantly import-dependent market,

with a majority of household appliances coming from countries such as China, Japan and Korea (that have already adopted test procedures similar to the IEC test methods),<sup>105</sup> aligning test procedures with IEC and ISO standards will significantly reduce regulatory compliance costs and burden for product suppliers. Periodic checks of the markets and warehouses will also ensure products that do not meet established standards would be identified and removed from the markets. Enforcement actions, if effectively conducted, would deter suppliers from engaging in the importation and supply of sub-standard products. However, based on respondents' feedback, poor durability of CFLs is identified as one of the major deterrents from the purchase of energy-efficient bulbs. The recent report by the United Nations Development Programme (UNDP) – Nigeria also substantiates the fact that some CFL bulbs in the country could be of poor quality. The UNDP study conducted compliance tests on CFLs that were randomly collected from markets in various locations within the country with results showing that 95 % of CFLs in the sampled markets do not meet the required standards (Uyigüe, et al., 2015, p. 22). Considering these facts, it could be interpreted that MVE measures probably needs to be enhanced.

### **8.6.3 ANALYSIS OF ENVIRONMENTALLY SOUND MANAGEMENT**

From the assessment of the NEEAP, reported policy instrument that has been implemented to ensure environmentally sound management of end-of-life products is the Extended Producer's Responsibility (EPR) program initiative which requires importers, producers, distributors of products to take adequate responsibility of life cycle management of their products by providing avenues to take back their products at their end-of-life. However, implementation strategies for the EPR initiative could not be ascertained by the time of this research. For instance, for CFL lamps, importers and distributors are expected to establish measures of collecting burned-out light bulbs. But considering the absence of designated collection systems for end-of-life CFL lamps as observed in the study area, it could be interpreted that enforcement of the EPR program has not been very effective or adequate awareness is not being created on the need for proper disposal methods for used lamps. The major challenge that such a strategic program may have in Nigeria is due to the predominantly unregulated (open) nature of the markets. For instance, there are an observed 206 different brand names of CFLs (Uyigüe, et al., 2015, p. 12).

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<sup>105</sup> A review of the report of the Commonwealth of Australia, Department of the Environment and Energy (2017, p. 21) reveals that Nigeria's major appliance trading partners (notably, China and Japan) have already aligned appliance test methods with the IEC test procedures.

Ensuring that each of these brand owners takes adequate responsibility for their burned-out products would involve huge coordination which may require high enforcement costs. Also, as recommended in the integrated policy framework, programs for the collection and processing of the steel, copper, aluminum, plastics and the refrigerant at the end of the product life of refrigerators and air conditioners, are not yet put in place.

## **8.7 CHAPTER CONCLUSION**

Based on the evaluation criteria adopted in the assessment conducted in this chapter, key policy instruments that would ensure an efficient operational framework of the integrated policy approach, are yet to be designed and/or implemented. The success of MEPS in achieving an energy-efficient appliance market transformation will depend on the existence of key supporting policies and a strong foundation of MVE programs. The design and implementation of appropriate financial instruments would make energy-efficient technologies more attractive to consumers. Considering published poverty count rates of the surveyed area, implementing financial incentive measures will reduce the burden of high initial investment costs of energy-efficient products thereby making them more affordable. Specially designed programs such as rebate and turn-in programs could encourage end-users to submit their old and inefficient appliances in exchange for new and efficient types. For example, a United Nations Development Programme (UNDP) report, retrieved from the UNDP official website, shows that a rebate and turn-in program embarked in Ghana in 2012 was successful in encouraging end-users to turn-in their old refrigerators, freezers and air conditioners in exchange for new and efficient types. Depending on the appliance, consumers received a minimum of US\$ 70 as a rebate to purchase a new appliance (UNDP, 2018). It was reported that about 15,000 units of refrigerators, freezers and air conditioners were exchanged by the end of 2015 (UNDP, 2018). A co-benefit of such a rebate and turn-in program is that it would minimize indiscriminate disposal of end-of-life appliances since the old appliances are collected during the swap.

Efforts should be made to ensure that products covered by MEPS that are manufactured or imported into the country meet established standards. Product quality will guarantee end-users confidence in energy-efficient products which is quite essential to consumer acceptance of efficient technologies.

Considering a region where energy efficiency is not yet well established, providing proper and adequate information on product packaging will also play a great role in guiding consumers' purchase decisions. Capacity building programs targeting retailers will equip them to provide expert information to end-users on how energy-efficient appliances can assist them in lowering energy costs and save money.

EnSM measures should be adequately implemented. Disposal mechanisms for CFLs should be developed and mercury waste management should be planned and established as early mitigation actions against environmental hazards that may occur from the accumulation of mercury waste from burned-out CFL light bulbs.

Finally, for the NEEAP to achieve an effective energy-efficient appliance market transformation, key policy instruments, as highlighted above, that are still in their planning stages and/or not yet developed or implemented (especially environmentally sound management and financial support programs), should be properly addressed. Also, efforts should be made to enhance the operational framework of the MVE program.

## **9. HOUSEHOLD LEVEL BARRIERS AND POLICY SOLUTIONS**

### **9.1 INTRODUCTION TO CHAPTER NINE**

This chapter discusses several observed factors that militate against the effective uptake of the MEPS program in the case study area. This research categorizes these factors into structural, social, political and technological barriers. The chapter also recommends policy actions and measures that can enhance the widespread diffusion of energy-efficient technologies in the region. The policy actions identified in the research include exemplars from global best practices for a successful standards and labeling program, drawn from reliable and objective policy evaluation studies and databases such as the World Energy Council (WEC), the International Energy Agency (IEA), and United Nations Economic Commission for Europe (UNECE). The policy options are by extension, integral parts of the integrated policy framework (see chapter 8), adapted using a tailor-made approach to present solutions to identified barriers. Factors considered in choosing best practice policy recommendations include; demonstrated significant outcomes or quantifiable results (especially huge energy demand and emissions reductions); adap-

tability to identified barriers and ease of integration to existing national policies and policy delivery mechanisms; and likelihood to attract utilities attention and investments.

Policy recommendations to overcome identified barriers are also drawn from key informant's recommendation during the conducted interviews. It should be stated that the degree of success of these actions will depend on effective governance, enforcement and timely review, evaluation and refinement of policies.

**Social barriers:**

- Lack of awareness: lack of end-users' awareness, especially on the benefits of using efficient appliances (such as energy and cost savings), hamper the widespread diffusion of efficient technologies. The end-user major motivation for purchasing electrical appliance is for the services that it provides; for instance, room temperature control from air conditioners, refrigerator food storage services or lighting services from light bulbs. Energy-efficient products exist that can deliver these services more efficiently and cost-effectively. Consumers, usually, do not take the advantage presented by these efficient technologies which are most often characterized by high initial investment costs. Consequently, they prefer cheap and inefficient products which end up creating unnecessary loads on the power grid without providing better services. From the household survey, while 55 % of the respondents consider appliance initial cost as a critical factor that informs their decision on the type of appliance to purchase, only 15 % claim the overall operational cost of appliance usage is more important. Inspiring consumers to adopt energy-efficient products would involve developing strategic ways of educating them on the medium- to long-term benefits of using efficient products. Such awareness creation would enhance end-users' acceptance of energy efficiency and also instill the necessary behavioral changes amongst consumers.
- Poor electricity access: The unreliability of electricity supply in the country seems to reduce the attractiveness of end-use energy efficiency. The majority of the respondents in the household survey (61 %) indicated that electricity is only available for about one to six hours per day. None of the respondents specified that electricity is always available when needed. The idea of energy savings would not make much sense to the people

considering incessant power interruptions. The general notion is the rationale behind the idea of saving electricity that is rarely available. Such believe, which impedes the diffusion of efficient appliances could be corrected by creating awareness programs and educating the masses that saving energy could improve electricity supply. Since electricity generating companies do not generate enough electricity to meet the demand of everyone at the same time, the use of efficient appliances could relieve national grid load and make electricity more available because energy saved can be made available to other regions.

- High presence of local technicians: The high presence of local technicians provides a form of encouragement for the purchase of old, used and inefficient electrical appliances. Used and inefficient appliances such as refrigerators and air conditioners are cheaper than new and efficient types. As described in chapter 7 of this research, some of these used appliances are imported and sold as non-functioning products to consumers and at very low costs. The capacity of the local technicians to repair these old and non-functioning appliances at relatively low charges makes the purchase and use of these products attractive and reduces the need or essence of buying new and more efficient types. This problem is exacerbated by the considerably high poverty level in the region. Information from the Enugu State Economic Planning Commission (ESEPC) on the poverty count in the state (table 8.5) shows that 38 % of the population lives below the international poverty line of US\$ 1.90 per day.

### **Structural barriers**

- Illegal connection and estimated billing systems: it was observed that some households devise various means to reduce energy costs such as bypassing electric meters to connect their loads directly to the grid thereby leading to scenarios where electricity consumption is not appropriately metered. Also, the estimated billing system is seen as a source of barrier to the advancement of the use of efficient appliances in households. From the survey conducted, 29 % of the respondents that indicated their electricity billing methods claimed that their electricity billing is based on estimates (see figure 5.7). In consolidation to this fact, information gathered from the questionnaire response from the local utility (EEDC) reveals that more than half of connected households



(472,147) within the utility's coverage district do not have either of the pre-paid meters or conventional meters. Such households get billed through an estimated billing system which implies that distribution companies bill consumers based on electricity consumption in a previous month. For those households on estimated billing, actual monthly consumptions may not be captured adequately. The estimated billing system arises due to the shortage of pre-paid or post-paid meters.

### **Regulatory associated barriers**

- Utilities lack of interest: Considering the direct contact of utilities (such as electricity distribution companies or DisCos) with consumers, they are strategically positioned to deliver appliance energy efficiency policies. During the interview with the local electricity distribution company in the region (EEDC), it was observed that encouraging consumers to adopt end-use energy efficiency measures are not considered as measures that can improve the operational efficiency of the utility company. Rather, it seems there is a notion that such energy efficiency measures would affect the business profit margin of the distribution company. Revenues are mainly generated from consumers' electricity bills and as such, it is believed that energy efficiency would reduce customers' bills due to reduced energy consumption; and this is seen as not very good for business. Furthermore, utilities' operations and revenues are already marred by various losses (technical, commercial and collection losses)<sup>106</sup> which reduce the utilities' business profits. Information gathered during a research interview with the key informant at EEDC, Engr. Fatai Olanipekun, indicates that consumers' bills do not reflect the operational costs of utilities. As a result, it could be interpreted that electricity bills are not cost reflective.<sup>107</sup> Engr. Olanipekun highlighted that utilities are not even able to pay for

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<sup>106</sup> Based on questionnaire responses from the interviewed personnel at the EEDC (Engr. Fatai Olanipekun), technical losses are the losses associated with network defects, commercial losses are those losses that are incurred as a result of energy theft such as meter bypass, illegal consumers and load diversion and collection losses are those arising from the uncollected billed amounts. It was further explained that technical losses account for almost 10 % of energy imported from the grid and commercial losses account for 18 % of the remaining 90 % of energy imported from the grid.

<sup>107</sup> Cost-reflective tariff or pricing should, in theory, charge consumers based on the costs they impose on network businesses and ensures that consumers cover the costs they cause which incentivize efficient investment and operations of network providers. United Nations Economic Commission for Europe (UNECE, 2015) highlights that several countries (Australia, New Zealand, EU, etc) have established liberalized electricity markets and prioritized cost-reflective tariff structure which has effectively motivated a wide range of sustainable development options,

the full charges for energy imported from the grid. Consequently, utilities such as EEDC may not have motivation for economic investments in energy efficiency of appliances. Strategically designed utility initiated programs targeted at enhancing the widespread diffusion of energy-efficient technologies could improve the operational efficiency of the utility companies and also, help create awareness for increasing end-use energy efficiency. A variety of voluntary and mandatory policy measures are available. For instance, providing discount vouchers to consumers for reducing energy consumption in a previous billing period. A 10 % reduction in energy use could attract a 10 % discount voucher that can be used in the next billing period. Such measures could instill energy efficient behavioral changes in end-users. Utilities can also engage in on-bill financing<sup>108</sup> programs to increase the consumers' uptake of energy-efficient technologies. On-bill financing provides funding to assist consumers to overcome upfront investment hurdle of acquiring energy-efficient products, allowing repayments to be made by the customer over time through his or her monthly utility bills. Bell et al. (2011, p. 1) report that, in some cases, consumers have been able to pay back funds with the money saved from their energy bills as a result of reduced electricity consumption from the use of more energy-efficient products. Utilities could install energy-efficient products in households of customers allowing repayment to be made by the customer through on-bill repayment structure. On-bill repayment mechanisms are seen as more convenient and advantageous when compared to other forms of energy efficiency finance measures that require the program participant to continue paying his or her utility bills concurrently with an additional bill from a separate financier (Bell et al., 2011, p. 1). Utility companies can utilize existing customer information on their database to assess consumer's creditworthiness. It is reported that several utilities in various states in the United States have implemented on-bill financing programs that have enhanced households' uptake of energy-efficient technologies which resulted in huge electricity savings (Bell et al., 2011, p. 2). For instance, in the state of South Carolina, on-bill financing programs have impacted about 195,000 homes resulting in 2,668,800 MWh of energy savings and

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especially energy efficiency, by ensuring that all stakeholders in an energy system get effective price signals for their activities. UNECE (2015) found out that the market impact of cost-reflective pricing is universal.

<sup>108</sup> On-bill financing is a method of financing appliance energy efficiency improvement using the utility bill as a repayment tool (Bell et al., 2011, p. 1).

2.4 million tonnes CO<sub>2</sub> emissions reductions annually (Bell et al., 2011, p. 8). Implementation of on-bill payment programs may provide possible benefits to utilities in Nigeria such as EEDC and the electricity sector as a whole. Benefits to utilities may include a reduction in grid congestions and peak demand and the costs of imported energy, avoided investment in grid expansion projects, reduction in electricity distributional costs and reduction in technical and commercial losses and its associated costs incurred by utilities. Irrespective of the listed potential benefits, it may be difficult for utilities to initiate programs to advance appliance energy efficiency unless such roles are prescribed or mandated in the relevant national electricity market regulatory policies. The transformation process of Nigeria's electricity sector did not address the role of utilities in championing energy efficiency. This could be regarded as one of the major challenges against utility engagement in advancing appliance energy efficiency in Nigeria. Other potential problems in the Nigerian context could be the source of capital to finance programs and providing opportunities for the customers that are most in need especially those living below the poverty threshold. Sources of finance for on-bill programs in the United States include both the public sector (grants from federal government and bond issues, etc) and the private sector (banks, credit unions, commercial banks and capital markets) (Bell et al., 2011, p. 4). It is reported that most utilities in the United States, use on-time utility bill payment as evaluation criteria for creditworthiness in order to make the program accessible for targeted households (Bell et al., 2011, p. 19). Utilities can also develop online-based energy calculators that consumers can use to estimate energy savings and economic impacts of energy efficiency investments; which will utilize a simple cash-flow diagram to express payback periods of such investments. This may assist in enhancing consumer awareness on the economic benefits of energy efficiency investments and encourage them to consider the long-term benefits of buying energy-efficient products. Utility developed online-based energy calculators are common practice in countries such as South Africa.

- Absence of labels: Labels have been classified as one of the most effective measures of delivering information about appliance energy efficiency to consumers (U4E policy guide series, 2017b, p. 34). They provide information on the energy performance of a

particular product which assists end-users to make informed purchase decisions and facilitate comparisons between products. Thus, end users can choose products with a high level of efficiency and quality. Although the Nigerian Energy Guide Label for consumer appliances has been developed by the Standards Organisation of Nigeria (SON) but as discussed in chapter 8, the absence of these labels on products limit energy efficiency information available to consumers. The effective implementation of the Energy Guide Labels will provide adequate information on the packages of products and assist consumers to make appropriate purchase decisions. For instance, for CFL light bulbs, the following information is required on lamp packages: life of lamp in hours, comparison factors such as luminous efficacy, lamp wattage of the CFL lamp and corresponding wattage equivalent of an incandescent bulb that the CFL can substitute (SON, 2010, p. 11). Information on the estimated period for the return on investment can also be provided on labels.

#### **Technical barriers**

- Proliferation of substandard products: Another major impediment to the diffusion of efficient products, especially light bulbs, is the incessant proliferation of substandard products. This issue reduces consumers' confidence in the reliability of the products and discourages them from buying CFLs. This measure needs government effort and political will to enforce compliance among importers and to strengthen the responsible agency/agencies such as SON in conducting appliance tests and confiscating substandard products. Adequate penalties should be enforced on defaulters which will serve as a deterrent to others.

## **9.2 RELIABILITY-FOCUSED BEST PRACTICE ENERGY EFFICIENCY PROGRAMS**

Based on the overall barriers identified in this research, the policy framework (table 9.1) is developed as part of recommendations for further actions. The policy framework is based on global best practices that have proven effective in similarly treated contexts such as in the United States of America, Europe and Australia and also, based on recommendations from interviewed persons in some of the visited government institutions. Efforts were made to adapt the framework in a tailor-made approach in response to significant barriers as observed in the research. The selection of these best practice measures was based on certain factors. The

following section presents a summary of these factors that were considered.

1. Targeted sectors: In consideration of the research scope, the selection of programs was carried out to mainly address end-use energy efficiency improvement in the residential sector. However, some of the programs can also be applied in the commercial and industrial sectors.
2. Program delivery mechanism: The programs were also selected having in mind the possibility of executing the recommended measures through already existing or planned program delivery mechanisms. Program delivery mechanisms that were taken into consideration include measures like incentive mechanisms, rebates, utility bill discounts, direct installation of products or pilot programs, ban of inefficient appliances, labeling, awareness campaign, etc.
3. Responsible administration: Organizations identified that could be in charge of program administration include, federal institutions, utility companies, stakeholders or representatives of business groups and not-for-profit organizations.

Table 9.1 is a summary of the recommended programs. The table provides specific information on major features of the program, such as responsible administration, targeted sectors, program delivery mechanisms and a concise program aim. The table offers a brief overview of the selected case studies and provides a quick comparison of the individual programs.

<b>Program type</b>	<b>Responsible authorities</b>	<b>Targeted sectors</b>	<b>Program aim</b>	<b>Delivery mechanism</b>
Residential lighting program (incandescent lamps still dominate as lighting source)	Federal institutions, DisCos, NGOs, representative of business groups	Residential (also, public and commercial)	To promote the attractiveness of energy saving lighting and transform the market for efficient lighting and lighting products	Incentives (such as rebates for efficient lighting and lighting products), awareness creation, free distribution of CFLs to low income households
Energy efficiency programs for the low-income residential group (based on the poverty count in the region, a significant percentage of the population live below the poverty line)	Federal and state agencies, utilities, NGOs	Low-income residential group (from figure 5.5, majority of respondents that considers appliance initial costs when making purchase decisions live in the type of housing units referred to as “rooms in buildings” which is mostly associated with low-income groups)	Program to assist low-income households with free energy efficiency services such as energy checks/audits, government-assisted direct installations of minor appliances such as CFLs	Incentives, government-assisted installations, awareness creation
Enhance distribution of pre-paid meters and establish mechanisms to check and trace meter bypass connections	Federal agencies, utilities (DisCos)	Residential (all sectors)	Programs aimed at improving the widespread installation of pre-paid meters and reducing illegal connection practices by households	Government financial support to enhance free distribution of pre-paid meters, setting up of special task force unit for surveillance on household illegal connection practices, monitoring household energy consumption trend and embarking on a further investigation when household’s energy use drops drastically, meters should be installed at conspicuous and elevated positions to reduce easy access to occupants
Incentive programs for local manufacturers and businesses	Federal agencies, financial institutions	All sectors	Energy conservation incentive programs to support local manufacturers and small businesses to produce and supply high quality energy-efficient and energy star-rated appliances	Financial support and rebates, tax reduction/exemptions, reduced import duties for energy-efficient appliances and manufacturing parts

State-wide energy conservation information and awareness campaign	Federal ministries and agencies (such as SON, ECN), utilities, NGOs	All sectors	A nation-wide (bottom-up) energy conservation campaign should aim to provide necessary and in-depth information on efficiency strategies and promote simple energy-efficient behavioral changes	Media, door to door messages, town chiefs, faith groups, online platforms. Faith groups should be involved in creating awareness due to the observed influence religion has in the study area.
Efficiency programs targeted especially at cities with huge energy usage	Federal and relevant state agencies	Residential and small scale commercial sectors	Energy efficiency programs especially in the residential and small-scale commercial sectors in targeted cities. This would influence other cities and result in significant load reduction. This program can be focused mainly on the major energy consuming appliances (lighting, air conditioning and refrigerators)	Rebates, incentives
Effective enforcement of minimum energy performance standards (MEPS)	Federal agencies (SON), relevant stakeholders	All sectors	MEPS, if effectively implemented, would prevent inefficient appliances from entering the market and would leave consumers only with the option of purchasing products that consume less energy. A detailed baseline market research and the establishment of a national energy data repository for appliances would guide ambitious MEPS for products and appliances and provide a basis for tracking MEPS impacts. MEPS should be reviewed from time to time to ensure conformity with technology advancement	Capacity building, enforcement and monitoring units
Implement the adopted energy guide labels for appliances	Federal agencies (SON), relevant stakeholders	All sectors	Energy ratings and labeling provide a quick assessment of the energy performance of appliances. It is aimed at increasing consumers' awareness and demand for energy-efficient products. In many developed economies (such as Australia and New Zealand), energy rating and labeling are mandatory for most appliances such as refrigerators, freezers and air conditioners. The Nigerian energy guide label displays a star rating from one to five. The more the number of stars, the higher the efficiency	Awareness creation, mandatory requirement to place the Nigerian energy guide label on appliances especially the most energy consuming appliances (lighting, refrigerators and air conditioners)

Energy Efficiency Resource Standards (EERS)	Federal and state agencies and utilities	All sectors	This program involves setting long-term energy targets for utilities which will mandate utilities to derive a stipulated percentage of their power supply through energy efficiency means. To achieve this, utilities would encourage and support strategies for end-use energy savings	Market-based trading system (tradable credits, financial incentives, rebates, on-bill financing, support programs to implement and aid eligible technologies)
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## **10. CONCLUSION AND RECOMMENDATIONS**

### **10.1 INTRODUCTION TO CHAPTER TEN**

The aim of this chapter is to highlight the main findings and contributions of the research as a whole. In respect to the outcomes of the research, the specific goals of this chapter are:

- To highlight the contributions of this dissertation to the current findings especially on the assessment of policy impacts of end-use energy efficiency measures such as MEPS.
- To provide answers to the research questions (RQ) posed in this thesis.
- To make recommendations that are based on the identified barriers in the research. The recommendations, which were developed in a tailor-made approach, can be adapted into the existing policy measures or incorporated into the integrated policy framework to achieve an energy-efficient appliance market transformation.
- To recommend areas for further research.

#### **10.1.1 CONTRIBUTIONS OF THE DISSERTATION**

This research contributes to different facets related to improvements in energy efficiency of appliances and addresses the nexus between data availability, effective policy design and trajectory for tracking impacts of appliance energy efficiency policy instruments.

First, the research responded to the lack of data on the evaluation of end-use energy efficiency policy instruments that have been adopted in Nigeria. By attempting the critical evaluation of MEPS, the research outcomes underscore the need to mainstream policy assessment practices in the energy efficiency sector in Nigeria as the country experiments with the growing political interests of increasing end-use energy efficiency.

Second, the study assessed the scale of impacts of current MEPS policy in Nigeria to understand the contribution of the current standards to national energy and emissions savings goals and to identify opportunities for the improvement of the current MEPS. This would contribute to knowledge on the possible impacts of adopting higher MEPS levels and provide the necessary background to weigh the costs and benefits of leapfrogging to more stringent MEPS levels.

Third, as a policy-oriented research, the dissertation offers a framework of recommendations related to improving appliance energy efficiency. The recommendations are based on global

best practices adapted based on identified barriers against the widespread diffusion of end-use energy efficiency using Enugu as a case study.

Fourth, the research also revealed the significant roles utilities such as electricity distribution companies (DisCos) can play in advancing end-use energy efficiency in Nigeria. The participation of DisCos in advancing end-use energy efficiency has received little or no attention in Nigeria.

## **10.2 MAIN CONCLUSIONS CONCERNING THE RESEARCH QUESTIONS**

From the findings of this dissertation, the performance of MEPS is more or less context-specific. The input parameters, baseline market efficiency levels and current levels of appliance standards influence the nature of the result. Assumptions adopted in the analysis should be considered when interpreting the results derived in the study.

*RQ 1: what are the use patterns and appliance ownership trends in the case study area?*

The justification of research question (RQ) 1 in this dissertation is viewed from the point that statistical results derived could provide details that can guide the design of end-use energy efficiency programs.

The majority of the surveyed households (89 %) already own different types of refrigerators. Refrigerator-freezer types are most prevalent. Based on the provided year of purchase, more than half (51 %) of the refrigerator-freezer types are older than ten years. Old refrigerators will be less efficient than new types. With 89 % saturation level in the surveyed households, and also considerably high per unit energy consumption, refrigerators represent part of household energy consuming appliance that should be effectively regulated. 9 % of the refrigerators in the surveyed households are relatively new (less than two years of purchase); this underscores the fact that the majority of the surveyed refrigerators in the households are likely of old stocks.

Room air conditioners have considerably low saturation levels (31 %) in the surveyed households. This means that the majority of future purchases for this appliance would be from households buying the products for the first time. Implementing MEPS and labels for room air conditioners at this moment presents a significant opportunity to achieve fast penetration of efficient room air conditioners in households. Furthermore, per unit energy consumption of room air conditioners are highest when compared to the other covered products in this research. This means that per unit energy efficiency improvement is high for this appliance; underscoring the need for a quick implementation of air conditioner standards and labels.

Incandescent light bulbs still dominate as lighting sources in the surveyed households. Nonetheless, households are gradually adopting CFLs, though at snail speed. The low penetration of CFLs could be attributed to their high initial costs, CFLs not lasting long enough and consumers being accustomed to the purchase and use of the conventional incandescent light bulbs (see figure 5.6).

*RQ. 2 Considering the appliances under review, how much residential energy and emissions savings can be achieved in the short- to medium-term period with the implementation of current standards?*

Considering national-level impacts, the current set of MEPS modeled in this research would cumulatively, achieve 34.3 TWh energy savings between 2019 and 2030. In consideration of cumulative BAU consumptions (in the absence of standards) of 107 TWh for all the covered appliances for the same period, this represents a reduction in the residential energy demand by 32 % for the modeled products. The estimated electricity savings would result in a cumulative CO<sub>2</sub> emissions savings of approximately, 15 MtCO<sub>2</sub>. The estimated emissions savings would contribute about 8.5 % to the total emissions savings target proposed in Nigeria's NDC report. The results from the policy impact assessment conducted in the research demonstrate the scale of energy and emissions savings impact of current standards and its contribution towards the pledges established in Nigeria's NDC.

*RQ 3. Are the existing policy measures and institutional roles effective to deliver very significant improvements in energy efficiency?*

The evaluation criteria adopted to study the existing end-use energy efficiency policies in Nigeria (the integrated policy approach) provided a platform to identify policy gaps in the NEEAP and also to reveal areas where implementation should be enhanced. Appliance energy efficiency measures, as detailed in the action plan, have been developed following the integrated policy framework. The assessment of the NEEAP shows that key supporting policies such as financial incentives are either still in their planning stages or not yet designed. Financial schemes such as tax cuts, rebate programs and on-bill financing would ensure that energy-efficient products are affordable which enhances their attractiveness. Adequate informative instruments (such as information labels on appliance packages) have not been implemented. Such labels provide information that guides consumers' purchase decisions at the point of sale.

Supporting policies are crucial to ensure the maximum impact of MEPS and encourage general public acceptance.

Monitoring, verification and enforcement (MVE) instruments have been designed and implemented. Appliance verification test procedures follow internationally recommended best practices. However, based on research findings, MVE measures need to be enhanced. The success of the energy-efficient appliance market transformation relies on effective monitoring, control and testing to ensure compliance with MEPS. In the absence of an effective MVE, the supply of sub-standard products would continue which will undermine savings and consumer satisfaction. Sub-standard products will put producers or importers that comply with established standards at a disadvantaged position thereby affecting the success of the MEPS program.

Environmentally sound management (EnSM) measures have been adopted; however, the implementation strategies and structures are still lacking. To minimize any environmental and health impacts from the use of efficient products (such as CFLs), special attention is needed to ensure that the Extended Producer Responsibility (EPR) initiative is adequately enforced. Also, facilities to confirm compliance with allowed mercury content levels in CFLs are not yet implemented. This would contribute to challenges in the control and management of mercury waste from the use of CFLs.

The assessment of the institutional mandates of key MDAs charged with functions of advancing end-use energy efficiency reveals the complexity of the sector. One of the most crucial findings from the assessment is that institutional roles in the NEEAP seem not to be based on the official statutory mandates of some of the institutions. This is especially observed for the Energy Commission of Nigeria (ECN) and the Standards Organisation of Nigeria (SON). For instance, the SON which has the capacity and facilities to conduct verification of standards has not been assigned with such roles in the action plan. The role of MVE in the NEEAP is solely dedicated to the Federal Ministry of Power (FMP). Even though the analysis of questionnaire and interview data did not reveal any clear overlap in MVE activities, a situation whereby FMP also engages in appliance standards' MVE roles as indicated in the action plan, would present a possible source of overlap and conflicts with the statutory mandates of SON and consequently, introduce

unnecessary regulatory burden and bureaucracies for suppliers of energy-efficient products who may have to present their products to different verification units for compliance testing.

Based on the above presentation, the identified policy gaps and the possible sources of overlap and conflict in institutional roles should be appropriately addressed. This may help in achieving an effective energy-efficient appliance market transformation in the country.

*RQ 4. What are the key challenges against the promotion of end-use energy efficiency in Nigeria?*

Apart from the institutional and policy barriers, several other key challenges against the advancement of appliance energy efficiency in Nigeria were also identified and discussed. These barriers, which are elaborately discussed in chapter 9 of this dissertation, are based on identified practices and respondents' feedback from the household survey conducted in Enugu. The identified barriers have been classified into social, structural, regulatory and technical barriers. The identified barriers guided the choice of policy measures presented in the recommended policy framework in chapter 9.

*RQ 5. How does energy savings potential study advice energy policies and its role in creating the political will to change a persistent policy direction?*

The research established empirical information and key design elements that could guide the planning and implementation of appropriate policy instruments for increasing end-use energy efficiency. Even though these findings are based on this study which is conducted on a particular region of the country, the findings can be applied to other parts of the country. The descriptive statistics on current appliance saturation levels, age distribution of appliances, the absence of proper informative labels on product packages, etc can guide the choice of supporting policy instruments for the uptake of energy-efficient products.

The assessment of the policy impacts of the current MEPS under varying policy scenarios reveals the possible savings that can be achieved from the current standards, the efficiency gaps that exist and the room for improvement of the current appliance standards. It also provided insight on the possible efficiency gains that can be realized from improving the current standards and the need to monitor innovations in technology advancement in order to prevent dumping of products of less efficiency in the Nigerian market and to ensure that MEPS remains effective. Since policy impact assessment relies on baseline market characteristics, this study

also underscores the need for a detailed baseline market assessment to establish clear baseline energy efficiency levels of major energy consuming appliances. Altogether, these findings could be utilized in the planning and design of the next standard and label programs in Nigeria and also allow for tracking the impacts of the reviewed standards in relation to a robust baseline. This would ensure that policy outcome reflect the solutions requiring the implementation of such a policy instrument.

Considering a region where the concept of energy efficiency is not yet well established, the derived results from the policy impact assessment can provide preliminary results (especially within the context of contributions of the derived savings to national energy and emissions savings goals) that can be used in consultations with policy makers on the need to see energy efficiency as an energy resource and a means to realize national climate goals. It should be mentioned here that other co-benefits of increased energy efficiency have not been considered in this study. The consideration and inclusion of these sets of co-benefits (such as cost savings by consumers and cost savings from a possible reduction on investments required for grid expansion projects) would enhance the socio-economic attractiveness of appliance energy efficiency improvements.

### **10.3 RECOMMENDATIONS**

This section highlights several considerations for the advancement of end-use energy efficiency in Nigeria. Even though the set of recommendations presented below is relatively based on global best practices, efforts were made to adapt such recommendations in consideration of the findings from this research. The recommendations presented here address the following stakeholders; (i) policy makers in charge of the design and implementation of end-use energy efficiency measures (ii) MDAs responsible for the operations, administration and enforcement of end-use energy efficiency measures (iii) electricity distribution companies and (iv) consumers.

#### *Justify the implementation of energy efficiency measures*

The policy objectives for the implementation of end-use energy efficiency as clearly stated in the NEEAP includes; to reduce greenhouse gas emissions, reduce appliance energy consumption, improve the security of energy supply and achieve an effective energy-efficient market transformation. Baseline market data guides the setting of appliance standards and

ensures that MEPS reaches higher levels than market baseline, otherwise there is no impact. Consequently, it is recommended that a thorough baseline market assessment should be conducted with key appliance features and characteristics. Such market analysis would reveal accurate baseline efficiency levels of appliances which can guide the review of standards that will reduce existing efficiency gaps and accelerate market transformation towards more efficient products. Detailed baseline market information would also serve as a form of data repository which can aid research in the area of appliance energy efficiency and assist in tracking progress and policy impacts of appliance energy efficiency policy measures.

*Establish a transparent and enforceable non-compliance structure*

Beside other factors, the effectiveness of end-use energy efficiency programs depends on the non-compliance rules and effective enforcement. To ensure that products being supplied in the market meet the required standards, regular monitoring of the market is recommended. In addition to non-compliance rules and considering the numerous brand names available in the market, responsible government agencies can develop a medium to inform consumers of those products (example, brands of CFLs) that have been proven to maintain a certain level of quality or standard. Such information would guide consumers' purchase decisions and ensure their satisfaction. Furthermore, such public information would spur manufacturers and importers of individual brand names to strive to maintain quality and ensure that their products are recognized by the responsible government agency as a reliable quality. It is also recommended that all non-compliance penalties should be set out in law and communicated to stakeholders.

*Ensure synergies and address possible overlaps in the roles of key MDAs.*

Policy instruments such as end-use energy efficiency measures rarely function in isolation. So it becomes necessary to analyze the implementation structures to identify areas of poor synergies and avoid overlaps. Possible overlaps may exist in the area of MVE roles between the Standards Organisation of Nigeria (SON) and the Federal Ministry of Power (FMP). Considering the SON's direct involvement in the establishment and development of standards and MVE activities with established facilities and capacities to carry out such roles, it is recommended that MVE role should be coordinated by the SON for smooth operations of MVE activities. Other institutions can liaise with the SON by providing support and/or advisory functions. A constant review

process of institutional activities is also recommended; this would allow overlaps to only exist temporarily.

*Develop a clear but simple institutional framework.*

The review of the institutional roles of the key MDAs in the advancement of appliance energy efficiency reveals the complexity of the sector. Each institution seems to have agencies performing similar roles. A clearly defined operational and regulatory framework is necessary to reduce the level of administrative burden. Assigning institutional roles to reflect statutory mandates of the MDAs is recommended. This would ensure that activities geared towards advancing appliance energy efficiency are assigned to institutions with established facilities and capacity to discharge such roles. This will make sure that such roles would be executed efficiently and will also reduce the possibility of overlaps and conflicts in the discharge of duties.

*Implement support policies*

The implementation of effective support and information policy instruments is needed. For instance, considering high poverty counts in the region and high presence of local technicians, it may be relatively difficult for end-users to willingly switch to the use of more efficient types of appliances without financial incentives to reduce the burden of high initial costs of energy-efficient products. Financial incentives will enhance the sales of best-performing products.

Also, this study recommends the active involvement of electricity distribution companies (DisCos) in championing end-use energy efficiency. The role of utilities in advancing end-use energy efficiency is considered crucial considering their direct interactions with consumers. DisCos also maintain and monitor energy consumption data of connected consumers and as a result, are in a strategic position to implement carefully designed financial mechanisms and also to track the impacts of such end-use energy efficiency measures. This study has developed a policy framework that suggests possible financial instruments with implementing institutions proposed based on their statutory mandates. The significant factor about this policy framework is that it adapts already existing delivery mechanisms and institutions. As a result, adopting and integrating this framework will be cost-effective.

Information and awareness campaigns should be intensified. This is necessary considering also, a region where energy efficiency is not yet well developed. Awareness campaigns targeting consumers should focus on energy costs savings from adopting efficient end-uses. Regulations



should consistently check and ensure that in-store and supplied products appropriately display the required information.

*Effective implementation of environmentally sound management measures.*

Special attention is needed to ensure that the policy instrument to encourage environmentally sound management (EnSM) of end-of-life products is effectively implemented. Developed programs such as the EPR and establishment of adequate disposal mechanisms, will help in minimizing possible environmental and health hazards that may result from the use of energy-efficient products such as CFLs. Awareness campaigns informing end-users on the need for proper disposal of end-of-life products will also contribute to the success of EnSM measures.

#### **10.4 FURTHER RESEARCH**

This research endeavored to provide a comprehensive assessment of end-use energy savings potential in residential homes in Nigeria, using Enugu as a case study. However, several aspects still need to be investigated. The concept for further research takes its departure from the conceptual background of the research (energy efficiency potential evaluation as policy-oriented research) and also, the expected contribution of increasing energy efficiency on national energy and emissions savings goal. Policy design and implementation come with associated costs. Cost-effectiveness examination plays a critical role in the choice of a policy instrument. Further research to ascertain if the benefits of recommended policies outweigh the costs would assist in understanding the cost implications of energy efficiency measures and also contribute to adopting policies that would yield maximum outcomes. Furthermore, as this research considered the impacts of improving the current standards to more stringent levels, a cost-effectiveness assessment would be necessary to reveal the financial impact of such a review on consumers and as well as the national financial costs and benefits of considering higher MEPS levels.

Also, considering the context in which the potential savings derived from this assessment are benchmarked (i.e. contribution to national emissions savings target and reduction in the electricity supply-demand gap), comparative assessment between end-use energy efficiency and other demand-side energy management measures, such as development and implementation of building codes, is recommended to ascertain the degree of contribution of each measure to national energy and emissions goals.

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## APPENDIX

### I. QUESTIONNAIRE (HOUSEHOLD SURVEY)

Interview number: .....

Date..... (day)/ ..... (month)/2016

Ward/Borough.....

Good [morning/ afternoon], my name is [interviewer's name] and I am conducting a survey for the [name of university]. The purpose of this study is to find out how your household uses electricity and what difficulties you may face in accessing new, more efficient appliances. This survey is part of research for my doctorate degree.

I anticipate that this survey will take about 20 to 30 minutes to complete. The information you give me will be kept confidential. You and your household will not be identifiable in any outputs from this study. If there are any questions you prefer not to answer, or if for any reason you want to withdraw from this study, you may do so at any time without giving a reason. Finally, if you have any questions or comments on this study, please ask now.

Thank you in advance for your participation.

Section A: Household information

INTERVIEWER: To begin with, I would like to ask you for some information about you and your household.

- |     |  |   |  |
|-----|--|---|--|
| A01 | Gender   | <input type="checkbox"/> Male   | <input type="checkbox"/> Female  |
| A02 | How old are you?   | <input type="checkbox"/> 18 – 29<br><input type="checkbox"/> 40 – 49<br><input type="checkbox"/> 60+                  | <input type="checkbox"/> 30 – 39<br><input type="checkbox"/> 50 – 59   |
| A03 | Are you the chief wage earner in your household?           | <input type="checkbox"/> Yes<br><input type="checkbox"/> No   |  |
| A04 | What is the principal occupation of the chief wage earner? | <input type="checkbox"/> Agriculture<br><input type="checkbox"/> Self employed<br><input type="checkbox"/> Unemployed | <input type="checkbox"/> Construction<br><input type="checkbox"/> Public sector<br><input type="checkbox"/> Private sector |

- Housewife                       Other (please specify)\_\_\_\_\_
- A05      What is the highest level of schooling completed by the chief wage earner?     No formal education     Primary  
 Secondary                       College/University  
 No answer
- A06      Who in your household makes decisions about electricity?     I do                               My husband/ wife  
 My son/ daughter               Jointly with others  
 \_\_\_\_\_ Other                      (please specify)\_\_\_\_\_
- A07      How many members of your household are there?
- A08      What is your average household income?     < 60 USD                       61 – 120 USD  
 121 – 180 USD                       181 – 240 USD  
 241 – 300 USD                       > 300 USD  
 No answer                      (at USD 1 = NGN 360)
- A09      Which of these options best describes the type of your house/ apartment?     Duplex                       Bungalow  
 Flats                               Room in buildings
- A10      Do you carry out any commercial activities from your house/apartment?     Yes  
 No
- A11      Including bathrooms, how many rooms are there in your house?

Section B Energy Baseline Data

INTERVIEWER: I would now like to ask you some questions about how your household uses electricity...

B01	Does your household have access to electricity?	<input type="checkbox"/> Yes <input type="checkbox"/> No	→ B02 → Skip to B10
B02	If yes, Which of the following types of electricity does your household have access to?	<input type="checkbox"/> National grid	→ Skip to B04
		<input type="checkbox"/> Community grid	→ Skip to B04
		<input type="checkbox"/> Stand-alone	→ B03
		<input type="checkbox"/> Unauthorised access	→ Skip to B04
		<input type="checkbox"/> Other (please specify) _____	
<input type="checkbox"/> Don't know			
B03	If stand-alone, how does your household get access to electricity?	<input type="radio"/> Solar home system <input type="radio"/> Gasoline/ diesel generator <input type="radio"/> Other (please specify) _____	
B04	How long does your household have access to electricity?	<input type="checkbox"/> Less than 1 year <input type="checkbox"/> More than 1 year <input type="checkbox"/> Don't know	

B05	How much did your household spend on grid electricity within the last 30 days?					
B05b	Tariff Class:					
B06	What is your average monthly electricity consumption					
B07	How do you pay for your electricity?	<input type="checkbox"/> Pre-paid <input type="checkbox"/> Post-paid <input type="checkbox"/> Estimated bill <input type="checkbox"/> Don't know				
B08	Whenever you need electricity is it available?	Never	Rarely	Sometimes	Often	Always
		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
B09	On average, how many hours a day is electricity available?	<input type="checkbox"/> < 1 hour per day <input type="checkbox"/> 1 – 6 <input type="checkbox"/> 6 – 12 <input type="checkbox"/> > 12 <input type="checkbox"/> No answer <input type="checkbox"/> Not available				
B10	Do you switch off your lights when going to bed?					
B11	Do you switch off your lights when going out or at day time?					

INTERVIEWER: The next set of questions focus on types of lighting in your home.

*For lighting, (If yes) How (If yes) Approximately, how (If yes) Approximately, does your many do you old do you think [bulb] is... how many hours per day household own? please, indicate wattage. do you use...?*

B12                      Incandescent light bulbs                       Yes                       No

- B13                      Fluorescent lamps                       Yes       No
- B14                      CFLs (energy saving bulbs)                       Yes       No
- B15                      LEDs                       Yes       No

*Does your household own (If yes) How many (If yes) Approximately, how old do you or rent any of the do you own/rent? think [appliance] is? Please, indicate following... power rating*

- B16                                      Air conditioning unit                       Yes       No
- B17                                      Refrigerator                       Yes       No
- B18                                      Indicate purchase                       New       Used  
status of appliance

INTERVIEWER: *Thinking now about the future...*

- |     |  |                          |                          |                          |
|-----|--|--------------------------|--------------------------|--------------------------|
| B19 | In the next five years, which appliance would you mostly like to own, upgrade and/ or replace? | Option<br>1              | Option<br>2              | Option<br>3              |
|     | Refrigerator   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
|     | Air conditioner  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
|     | Other (please specify)   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
|     | Nothing, I have everything I want  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

SECTION C: Energy Efficiency

INTERVIEWER: Thank you. Moving on to the final section of this questionnaire, I would now like to ask you some questions about why you choose to buy or rent the appliances you use, and what information is important when you are buying or renting a new appliance...

- C01 Thinking about the last time you bought or rented an appliance, what was the reason for doing so?                       To have an appliance that I've never had before                       To replace an old/ damaged appliance



- To upgrade the appliance
- The appliance was on promotion/ discount
- Other (please specify) \_\_\_\_\_
- Don't know

INTERVIEWER: If you want to find out more information about which appliance to buy or rent, which of the following advice source would you rely most on?

- C02 Friends/ family/ neighbours
- C03 Internet
- C04 The shop/ retailer/ manufacturer
- C05 Adverts
- C06 No answer
- C07 Other (please specify)

INTERVIEWER: When you are deciding which appliance to buy or rent, how important is each of the following?

- C08 How much it costs to buy/ the price
- C09 How much it costs to operate/ whether it leads to a reduction in my fuel bill/ how much energy it uses
- C10 The brand/durability
- C11 Impacts on the environment

C12	Would you be willing to pay more for a product initially if it cost you less money to run? Why?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Don't know
-----	--	--

C13	<p>Imagine you are going to buy a new refrigerator. You have two options, which are identical in every way except that:</p> <ul style="list-style-type: none"> <li>• Refrigerator A will cost you 100 USD</li> <li>• Refrigerator B will cost you 150 USD</li> </ul> <p>In two years, the electricity saving of refrigerator B will be 60 USD. Which of the two refrigerators would you buy?</p>	<input type="checkbox"/> Refrigerator A <input type="checkbox"/> Refrigerator B <input type="checkbox"/> Don't know
C14	Why?	

D01. And finally, is there anything we have not covered in this interview that you would like to tell me about your use of electricity and other fuels?

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Thank you for taking the time to complete this questionnaire

## II. QUESTIONNAIRE (INSTITUTIONAL MANDATES AND ROLES OF KEY MDAs)

This short questionnaire attempts to understand specific roles and mandates of your ministry or your agency in the area of appliance energy efficiency especially in respect to planning and development of the national energy efficiency action plan (NEEAP), setting and implementation of appliance minimum energy performance standards (MEPS), activities in the area of monitoring, verification and enforcement of established appliance standards, advisory or support roles to champion appliance energy efficiency.

Please, simply indicate yes/no in the following activities and kindly rate your level of engagement.

1. Energy efficiency policy planning (member of the Inter-Ministerial Committee on Renewable Energy and Energy Efficiency (ICREEE):  Yes  No

Please, briefly specify key activities in the planning and development of the NEEAP.

Rate your level of involvement:

(1) Very active role (2) Moderate role (3) Not active (4) No role

2. Setting and Implementation of MEPS  Yes  No  
please, briefly specify key activities such as:

National consultations with policy makers

Adoption of the energy guide labels

Phase out of inefficient products

Establishment of appliance standards based on baseline market research

Adopting ECOWAS harmonized MEPS

Other (please specify) .....

Rate your level of involvement:

(1) Very active role (2) Moderate role (3) Not active (4) No role

3. Monitoring, verification and enforcement of MEPS  Yes  No  
Please, briefly specify key activities such as:

Operation and maintenance of test facilities where com-

pliance to MEPS are verified

- Appliance inventories
- Monitoring imports/exports of efficient products
- Periodic checks of markets and warehouses
- Set penalties for non-compliance
- Confiscation of sub-standard products
- Other (please specify) .....

Rate your level of involvement:

(1) Very active role (2) Moderate role (3) Not active (4) No role

4. Mention any other advisory and/or support role/services in the area of appliance energy efficiency you are engaged in:

- Awareness campaign
- Conducting baseline market studies
- Conducting energy audits in buildings
- Funding energy efficiency R&D
- Pilot projects
- Design and adoption of incentive mechanisms
- Other (please specify) .....

Rate your level of involvement:

(1) Very active role (2) Moderate role (3) Not active (4) No role

**Please, kindly provide more insight on the following activities**

- Are there any planned and/or ongoing environmentally sound management (EnSM) measures for burned-out CFL bulbs, discarded ACs and refrigerators?

- Any measure(s) put in place to verify and/or enforce compliance concerning mercury content level of CFL lamps? Is your agency responsible for this? If yes, which is your key role (monitoring, verification and/or enforcement)? Please, kindly rate your level of involvement.

(1) Very active role (2) Moderate role (3) Not active (4) No role

**Thank you for your kind attention.**

### III. QUESTIONNAIRE (ENUGU ELECTRICITY DISTRIBUTION COMPANY - EEDC)

This questionnaire attempts to understand current status and mode of operation of your institution in respect to electricity distribution within your district. Please, kindly provide brief responses to the following questions. Your kind attention is highly appreciated.

- How many districts are you responsible for?
- What is the population of connected customers in the whole district?
- What amount of electricity is allocated to your company for the districts that are under your jurisdiction?
- What is the total daily electricity demand for your connected users?
- How much electricity is available for distribution daily?
- What is the average annual electricity demand for Enugu?
- How much electricity is available for consumers in Enugu?
- By your assessment what is responsible for the overall demand-supply gap? (briefly)
- Are there steps and/or measures taken by your company to bridge this demand-supply gap?
- If yes, please briefly enumerate these measures (eg. Encouraging end-users to reduce energy consumption by using energy-efficient appliances, designing programmes that could encourage end users adoption of energy efficiency, such as carrying out free energy audits in households, etc); free installation of pre-paid meters that would instill energy efficiency behaviors in consumers as they become more conscious of their consumptions, etc.
- If no, please briefly highlight what could be the major constraints (eg. Limited financial resources, lack of trained staff, lack of interest from management, programme may not yield financial prospects for utility, etc)
- Is there any planned or ongoing grid-expansion project being executed by your company? If yes, what is the capacity (in MW) of this project, location and the population it will serve?
- What measures are used to bill consumers' consumption (eg. Pre-paid meters, conventional meters, estimated billing, etc)?
- Can you estimate how many consumers have pre-paid meters installed and how many are still using conventional meters? Can you estimate the number of consumers that are on estimated billing?
- Do you think the conventional meters and estimated billing effectively captures consumers' consumption?
- What are the major loses for your company?
- Are these loses reflected in consumers' bills?
- What measures would you suggest to improve widespread installation of pre-paid meters in households?
- Can you estimate how long it may take to achieve a 100 % free installation of pre-paid meters for your connected consumers or within Enugu?

**Thank you for your kind attention and the time taken to respond to the questions.**

#### IV. LIST OF RELEVANT NATIONAL ACTS AND LAWS

National Electricity Power Policy (NEPP) of 2001
Electric Power Sector Reform (EPSR) Act of 2005
The Roadmap Sector Reform Act of August 2010
The Energy Commission of Nigeria (ECN) Act (No. 62) of 1979 Amendments: Act (No. 32) of 1988 and Act (No. 19) of 1989
Environmental Impact Assessment (EIA) Act (No. 86) of 1992. Gazette 79 (73), Federal Republic of Nigeria, FCT, Abuja.
National Environmental Standards and Regulations Enforcement Agency (NESREA) Establishment Act 2007
Standards Organization of Nigeria (SON) Act 56 of 1971 Amendment: SON Act 2015

#### V. RELEVANT INTERNATIONAL CONVENTIONS NIGERIA IS A SIGNATORY

International Conventions	Signature	Ratification
The Montreal Protocol on Substances that Deplete the Ozone Layer	31 October 1988	29 January 1989
The Kigali Amendment to the Montreal Protocol	-	-
The Minamata Convention on Mercury	10 October 2013	-
United Nations Framework Convention on Climate Change (UNFCCC) 1992	13 May 1992	29 June 1994
Vienna Convention for the Protection of the Ozone Layer 1985		31 October 1988
Paris Agreement 2016	22 September 2016	16 May 2017 (date of communication of first NDC)